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ABSTRACT

This manual was designed to furnish information for upgrading the design of wastewater treatment plant facilities and to serve as a resource for establishing criteria for upgrading these plants. The manual also furnishes information for modifying plant design to compensate for current organic and hydraulic overloads and/or to meet more stringent future treatment requirements. In addition, the importance of modifying existing plants and designing new plant facilities to accommodate operation, maintenance, and other routine plant functions is emphasized. Information is presented in 17 units, with objectives, text material/figures, and resources provided for each unit. Unit topics include: maximizing plant operations feedback in wastewater treatment plant design; plans and specifications reviews; general design considerations; unit process design for preliminary treatment, primary sedimentation, aeration basins, secondary sedimentation, disinfection, effluent discharge, sludge treatment, additional biological processes, and other factors (safety, energy conservation, and emergencies); systems approach to unit process selection; equipment selection/placement (for operability and maintainability); and operator/design engineer relationship. A FORTRAN computer program (with abridged users guide) for the preliminary design of wastewater treatment systems is included in unit 15. It is assumed that the user of this manual has an engineering background and is familiar with wastewater treatment plant design. (Author/JN)

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ED224684

A COURSE ON OPERATIONAL CONSIDERATIONS IN WASTEWATER TREATMENT PLANT DESIGN

STUDENT MANUAL

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Prepared for:

U.S. Environmental Protection Agency
Municipal Operations Branch
Washington, D.C. 20460

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SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO HOUSTON

STOTTLER STAGG & ASSOCIATES
ARCHITECTS, ENGINEERS, PLANNERS, INC.
SAN ANTONIO, TEXAS 78228

SE 040 747

SOUTHWEST RESEARCH INSTITUTE
Post Office Drawer 28510, 6220 Culebra Road
San Antonio, Texas 78284

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SwRI Project No. 14-6548
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Prepared by:

Southwest Research Institute
P.O. Drawer 28510
San Antonio, Texas 78284

and

Stottler Stagg and Associates
4538 Centerview Dr., Suite 151
San Antonio, Texas 78228

Prepared for:

U.S. Environmental Protection Agency
Municipal Operations Branch
Washington, D.C. 20460

June 1982

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FOREWORD

The main purposes of this manual are to examine seventeen areas of consideration for upgrading the design of wastewater plant facilities, and to serve as a source of reference for establishing criteria for upgrading wastewater treatment plants. The manual also furnishes information for modifying plant design to compensate for current organic and hydraulic overloads and/or to meet more stringent future treatment requirements.

This manual emphasizes the importance of modifying existing plant and designing new plant facilities to accommodate operation, maintenance and other routine plant functions.

The numerous types and sizes of treatment plants which require periodic updating necessitate a thorough understanding of the fundamentals of the various types of existing treatment units and associated unit operational procedures.

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INTRODUCTION

UNIT 1

UNIT 1 - INTRODUCTION

COURSE OBJECTIVES

At the conclusion of this presentation of the course the participant shall be able to:

- Identify wastewater treatment plant designs which avoid operational problems associated with meeting effluent criteria.
- Maximize plant design operations feedback.
- Prepare reports, plans and specifications for reviews.
- Design unit processes with optimum operability, flexibility and maintainability.
- Incorporate a unit selection process using a systems approach.
- Select and place equipment for operability, flexibility and maintainability.

UNIT 1 - INTRODUCTION

I. BACKGROUND

Water management is not a product of the twentieth century. Sewerage systems have been in existence for more than 5,000 years. Ancient Babylonia and Jerusalem had sewerage systems and ancient Rome had an elaborate system to convey more than 100 million gallons of water per day into the city and carry waste from the city. The primary function of the early systems was for the transporting and disposal of surface waters. The transport of waste material was secondary.

Wastewater treatment has been practiced from the latter part of the nineteenth century to the present to prevent water pollution. The activated sludge process, acclaimed to be one of the most effective processes to achieve secondary effluent standards, was first employed by Dr. Fowler in 1914.

One of the most perplexing problems for treatment plant operators is the ability to maintain the facility to meet regulatory requirements. The perfect treatment plant has yet to be designed. The best designed plant operated by the most highly skilled plant operators cannot achieve the desired effluent quality unless the plant equipment is operative. Considerable detail is usually given to equipment design and installation. Similar effort must be given to "how and when" maintenance work should be performed. These and other principles are sometimes overlooked by both the Design Engineer and the Operator. Guidelines based on operation experience will be presented to establish a workable relationship between the Design Engineer and the Operator.

The Federal Water Pollution Control Act Amendments of 1972, PL92-500, established specific goals for controlling wastewater discharges to meet certain water quality objectives. The primary function of designing and building wastewater treament plants is to produce a treated effluent of desired quality. The Design Engineer, after careful consideration, must commit his available resources to design a facility to meet these requirements to supply the municipality with a suitable facility. Economic considerations include: (1) municipal revenue availability, (2) land availability, (3) regulatory requirements, (4) available work force and (5) future plant upgrading or modification.

The Design Engineer and the Operator must work together to insure (1) optimum facility design, (2) proper construction and equipment installation, (3) adequate personnel training, (4) optimum operation and (5) adequate maintenance. The Design Engineer must formulate the goals and objectives into a treatment plant designed to meet regulatory requirements.

II. COURSE GOALS

This course is designed for practicing consulting and design engineers, plans and specifications reviewers/approvers, public agency officials, and state or other agency training personnel.

The content of this course stresses the importance of incorporating operational control, flexibility and maintainability into the design of wastewater treatment facilities. The course focuses on practical, field-proven approaches to improving performance through good design. A course problem or workshop discussion following a visit to an operating wastewater treatment plant will be used to assist in applying the course concepts and methodologies to actual plant situations.

III. MANUAL GOALS

The purpose of this manual is to provide technical guidance for persons involved in the design and/or evaluation of a wastewater treatment plant, such as a design consulting engineer or a state or federal regulatory agent.

This manual furnishes information of primary importance to persons involved in designing wastewater treatment plants which provide maximum operational control, flexibility and maintainability. The most commonly recognized limitations which affect plant operation are identified and described, along with suggested correctional measures, in the manual.

It is assumed that the manual user has an engineering background and has a general familiarity with wastewater treatment plant design.

IV. MANUAL FORMAT

In order for this manual to be an effective tool in wastewater treatment plant design, one should be familiar with the organization of the manual.

Table of Contents--Quick location of specific content areas

Unit Objectives--Specific outcomes to be expected from the information provided in each unit

Unit Text and Figures--The body of the presentation

Unit Resources--References and sources for additional information

FIELD EXPERIENCE: DESIGNING FOR OPERABILITY

UNIT 2

UNIT 2 - FIELD EXPERIENCE: DESIGNING FOR OPERABILITY

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- Identify wastewater treatment plant designs which avoid operational problems associated with meeting effluent criteria.
- Recognize and provide design features to deal with flow changes.
- Recognize the effect of combined sewers on the operation of wastewater treatment plants.
- Recognize the effect of industrial wastes on the operation of wastewater treatment plants.
- Plan a wastewater treatment plant design so the degree of complexity is compatible with the skills of the operator.
    - Identify a wastewater treatment plant where the degree of automation is compatible with operational and maintenance skills of the staff.
    - Identify a wastewater treatment plant which incorporates only that automation equipment which is cost, labor and energy efficient.
- Provide a plant layout that:
    - Is suitable to the geographic location.
    - Minimizes movement during operation and maintenance procedures.
    - Enhances access to equipment.
    - Minimizes environmental effects to the neighborhood.
    - Is designed to operate in the climate of the area.
    - Provides for minimal manual labor in material handling.
    - Provides hydraulic arrangement, distributes flow equally and provides flexibility for outages.

- Provides operator with flow measurement devices and controls for process operation.
- Is capable of handling flow under all conditions.

UNIT 2 - FIELD EXPERIENCE: DESIGNING FOR OPERABILITY

I. INTRODUCTION

The success or failure of a wastewater treatment facility in meeting its discharge criteria depends not only upon process design, but also the operability of the plant. A well designed treatment facility cannot be run successfully if the operators are not provided with the flexibility to cope with day-to-day variations in wastewater characteristics, and the means for maintaining peak plant performance. In order to accomplish these goals, the designer must be acquainted with plant operation and the situations operators find themselves in every day.

The primary function of a wastewater treatment plant is to produce a treated effluent that meets required criteria. The National Pollutant Discharge Elimination System sets forth effluent limitations to be met by a treatment facility. Additionally, the System describes the frequency of sampling, the type of samples to be taken and the analyses to be performed. The law requires that the results of these analyses be submitted to the United States Environmental Protection Agency (USEPA) on a monthly basis. This type of regulatory monitoring and enforcement places a burden on the operator to achieve consistent plant performance and on the designer to insure that the operator can reach this goal.

The Environmental Protection Agency's definition of secondary treatment has an impact on the designer's approach to effluent quality. Up until the time of publication of this definition, 85 percent removal of biochemical oxygen demand (BOD) was expressed as annual average performance. This would allow some months of the year to be in the 75 to 80 percent range, while the best months of the year might be 90 to 95 percent. However, the current USEPA definition requires 85 percent BOD removal as a monthly average in the worst month of the year. This means that plants must obtain average annual removals of 90 percent or better in order to be certain that the worst month will be above 85 percent. Plants whose influent BOD's are greater than 200 miligrams per liter (mg/l) now must meet the 30/30 BOD and suspended solids requirement. In the case of a plant whose influent BOD is 300 mg/l, this will mean that 90 percent removal is the allowable amount for the worst month and thus nearly 95 percent removal should be designed for in order to ensure that monthly removals will always be above 90 percent.

Compliance with these regulations requires that the design of secondary treatment plants be more conservative than it has been in the past. Moreover, the role of the operator in achieving required performance is now much more critical. The recognition of the operator's needs in carrying out his responsibilities must, therefore, be of prime importance to the designer.

II. DESIGN ASPECTS FOR OPERABILITY

A. Influent Flow and Load Variations

As the objective of every treatment plant is to produce an effluent of a certain quality, it is essential that the influent flow and load variations be determined and allowed for in the design of the facility. Historically, average flows and loads have been used as a basis for designing unit processes. Even today, many regulatory agency criteria list only recommended average values. In general, these criteria will work under average conditions but they may not be adequate in other situations. In terms of flow variations, a classic example of an improperly applied average is in the use of the 800 gallons per day per square foot surface overflow rate in secondary settling tanks. This criterion was developed many years ago in larger plants that did not experience peak flows much greater than 1.5 times the average flow into the plant. However, in recent years, the same criterion has been applied to treatment plants which frequently receive peak flows in the order of three to five times the average flow. The application of this criterion improperly sizes surface overflow rates which can result in solids washouts and deterioration of effluent quality.

Many treatment plants, particularly those on new or developing sewer systems, will start up at flows and loads as low as 10 to 20 percent of design capacities. It is essential that these initial conditions receive as much consideration by the engineer as the design conditions. Frequently, metering devices are oversized for initial flows, resulting in the operator being ignorant of the quantity of wastewater and sludge moving through his plant. Additionally, lack of consideration of the initial conditions may result in oversizing equipment such as pumps, blowers, chlorinators and chemical feeders. If these are not controllable at low flows, operation of the plant can be neither efficient nor economical. Wide disparities between initial and design flow conditions will necessitate equipment that can be changed out or altered to accommodate increasing flows.

A major area often overlooked in the sizing of critical treatment plant components is the effect of recycled loads from sludge processing operations. Returns such as digester supernatant, thickener overflow and heat-treated sludge liquors must be assessed in the selection of an overall treatment system. Allowances must be made for their presence, including BOD, suspended solids and nutrients, if a given plant is to function properly.

B. Industrial Waste Associated Problems

A circumstance that can present the operator with unanticipated variations in influent quantity and quality is the presence of industrial wastes. In many cases, industrial load and flow data are furnished by a company based on optimum operation within their plant. This optimum may not occur too often. Therefore, it is important to obtain independent data for correlation with information provided by industry, and to determine possible fluctuations that may occur in flows and loadings. The effect of toxic chemicals on biological systems must be anticipated. Detailed knowledge of industrial operations, products and effluents may have a profound influence on the type and sequence of treatment processes.

The rate at which an industrial waste is produced can affect biological treatment and must be considered in design. For example, an industry may generate a waste load of 1,000 pounds of BOD for eight hours every day. The actual rate of production is 3,000 pounds per day within the time period that the waste is generated. Therefore, it will be necessary to increase the size of tanks, blowers, aerators and other equipment to accommodate peak industrial load at the time it occurs. It may be more cost effective to require the industry in question to discharge during low flow periods, or to install an equalization basin in lieu of increasing the size of plant components.

The physical and chemical characteristics of an industrial waste can have important implications for treatment plant operation. For example, scum handling and anaerobic digestion may be adversely affected by the presence of large quantities of grease and oil. Additionally, sludge permeated with grease and oil can be difficult to dewater and incinerate. Certain industrial wastes may create odors when thermally conditioned; others may contain debris which will interfere with pumping and mixing of sludge; some wastes may not lend themselves to particular types of dewatering equipment; and others may require more than the normal horsepower needed in activated sludge systems because of the effect of the waste on oxygen transfer coefficents.

The contributions from all important industrial users of a municipal treatment facility must be considered if the process design is to have an effective capability of producing an effluent of consistent quality. Insufficient design capability resulting from incomplete or incorrect base information may force the operator to devote an inordinate amount of his time to dealing with process treatment, thereby neglecting maintenance and other duties.

C. Siting Needs

Considerable design experience is necessary to fully understand the treatment process and its variations. However, frequent visits to treatment plants, discussions with operators and the act of involving operators in facility design are important and can result in a more efficient, capable final design. Such visits will help the engineer focus on the many non-process related facts that are supportive to plant operation.

Facility layout can have an aesthetic impact as well as contribute to maintenance and operation of the plant. Wherever possible a wastewater treatment plant should be buffered from the surrounding community. If a plant is visible to the public, the use of grass in all nonpaved areas will enhance the appearance of the facility. It is recommended that trees and shrubbery not be used on facility grounds as this type of vegetation can obstruct views and drop debris into open tanks.

In small to medium sized plants, it is desirable to cluster unit processes around a centrally located operations building. Frequent maintenance is promoted if distances between components are small. In smaller plants, or where area is at premium, rectangular tanks can be used to save space and simplify expansion through the use of common-wall construction. However, it is necessary to provide enough access across tanks to enable operators to easily service all portions of the basins. Redundancy in size of multiple units of a single process will also help simplify maintenance and operation.

D. Flow-Into the Facility

The successful operation of a wastewater treatment plant requires thoughtful design in process operation and maintenance. All instream processes such as bar screens and comminutors should be designed to allow isolation as required, easy draining capabilities and easy access for routine servicing. Flow divisions in channels should be preceded by fairly straight channel runs to reduce losses and insure equal distribution of flow. Often, a single distribution channel is provided for a battery of tanks operated in parallel. Enough head loss should be provided at the entrance of each tank to be certain of an equal distribution of wastewater among the tanks.

E. Aeration Basins

The monitoring of the concentration of dissolved oxygen (DO) in aeration basins may be used as a feedback control mechanism for throttling on the blowers. However, it is important that the DO probes be serviced on a daily basis to keep them accurately reading the oxygen concentration in the basins. In cold climates, open tanks can be subjected to freezing over in winter. High freeboards on tanks and trickling filters will help alleviate icing on these structures. Ice formation on aerators in activated sludge reactors can be prevented by using shroud plates. Return activated sludge (RAS) must be carefully controlled to maintain adequate secondary treatment. A visible discharge pipe for RAS into the reactors will aid operators by focusing attention on return sludge characteristics and quantity.

F. Flow Control

Overflow weirs on 50 to 100 foot diameter secondary sedimentation tanks should be offset 1/4 to 1/3 of the radial distance from the wall in order to minimize upflow velocities into the weirs. For tanks larger than 100 feet in diameter, two concentric weirs should be designed. Other types of flow control structures are used elsewhere throughout wastewater treatment plants. If slide gates are used, it is necessary that the gate and slide be composed of the same metal to prevent binding and excessive wear.

Slide gates located between adjacent tanks can provide flexibility of operation by permitting the tanks to be used separately or together. Flow control can also be achieved by designing troughs that can be mechanically moved to permit more or less wastewater to overflow into the trough.

G. Flow Measurement

Parshal flumes are commonly used for flow measurements. A sufficienty straight upstream run above the flume should be provided. This will ensure that flow is uniform before entering the flume and the potential for accurate measurements is increased.

H. Solids Handling

Waste solids handling is one of the least desirable aspects of operating a wastewater treatment plant. For this reason, design of solids handling facilities should incorporate as many features for easy maintenance as possible. Bar screen cleanouts should be easily accessible with adequate utility piping within easy reach to keep the entire area clean and free of debris. Screen rooms and grit disposal areas should be provided with truck access if these materials are to be hauled off to disposal. In small plants, it is difficult to avoid manual handling of waste solids. However, wherever possible operators should not be required to lift buckets filled with grit or screenings. Collection bins on wheels should be provided. If manual handling is required, the disposal area should be on the same elevation as collection to prevent operators from having to walk on stairways with waste solids. The use of overhead clamshell buckets can eliminate the need for submerged grit removal equipment, and can facilitate the transfer of grit directly from a collection bin to a truck for disposal. Conveyors can be used to transport grit or screenings from several collection areas to a common dump point.

Positive displacement pumps should be used to handle scum collected on primary and secondary sedimentation basins. The scum can be pumped to thickeners and then combined with waste sludge for disposal. If scum pumping is not provided, scum will have to be disposed of separately. Often, ultimate disposal of liquid waste sludge involves trucking the sludge to a landfill or land application site. If the site permits it, overhead piping to tank trucks will make loading of the waste easier.

I. Use of Automation

Automation should be used judiciously, especially in small and medium sized plants, since it can be difficult to train operators to service sophisticated control systems. The major criteria for use of automation should be that it will insure a more reliable and consistent effluent quality, or significantly reduce labor, chemicals, energy or other costs. All instrumentation should be prominently displayed with indicators that are quickly and easily read.

J. Hazards Consideration

The chlorine room is an area that requires special attention to detail due to the hazardous nature of the chemicals it contains. Electrical hoists for up to one ton cylinders of chlorine are recommended. Indicating and recording scales for each cylinder in use should be provided. The chlorine room should have access only to the outside through double doors equipped with panic bars. The doors should include clear untinted windows for viewing the chlorine room from the outside. Fire and safety equipment should be very visible and within easy reach.

K. Cleaniness and Hygiene

A major portion of wastewater treatment plant maintenance is devoted to cleaning. Designers should consider this fact and include design features that reduce the need for frequent cleaning, as well as provide for components that facilitate cleaning when it becomes necessary. Dust, from equipment such as incinerators, should be prevented from accumulating on walls and other equipment. If this is not possible, sensitive components, such as electrical instrumentation, should be isolated from dust producing processes. Likewise, sludge processing is a messy operation, and should be isolated from sensitive equipment. All sludge handling components should be readily accessible for cleaning and tanks should be equipped with a suitably sized drain that enables operators to empty and clean it within a single 8-hour shift. Structures subject to solids deposition, such as channels and chlorine contact chambers, should be equipped with agitators to keep the solids in suspension. Floor drains should be located in all areas where water may accumulate.

Personal hygiene is an important part of cleanliness at wastewater treatment facilities. Sinks, with hot water, should be located next to laboratory facilities and in areas where cleaning is a frequent part of maintenance. Employees should be required to wash themselves regularly after exposure to undesirable materials.

L. Machinery Layout

Machinery must often be moved to be repaired. For this reason, cranes are required wherever heavy equipment, such as influent pumps, is located. Where the lifting power of a crane is not necessary, lifting inserts should be used above equipment. Care must be taken that equipment or support beams do not interfere with the travel of cranes on monorails. It is recommended that monorails be extended all the way to and/or through overhead door openings wherever possible. This will enable operators to move and load equipment onto trucks with a minimum of manual labor. Equipment galleries should be designed with wide enough aisles to permit movement of dollies or fork lifts.

The location of equipment can have important consequences for efficient operation. Large components, such as vacuum filters, should not be located in areas with low overhead clearance or with little room to maneuver. Processes requiring regular sevicing should be located away from hazardous areas such as stairwells or open machinery. Blowers and centrifuges generate a great deal of noise and should be situated in rooms with low ceilings and sound absorbing floors and walls. Care should be taken not to position valve hand wheels behind pipes where the wheel can be reached only with difficulty, or not at all.

Other common non-process equipment, such as electrical switches and light fixtures, must be located not only where they are needed, but also within fairly easy reach of plant personnel.

M. Piping

Pipe galleries can be difficult to service if not designed properly. All piping should be visible and readily accessible. Pipes should not be positioned one behind the other where an operator cannot reach them. Pipes should be labeled (preferably color coded) with the type of material they are carrying and the direction of flow. Pipes carrying caustic materials should be isolated or placed at a lower level than other nearby pipes so that leaked substances will not drop onto other piping. Aisles in the galleries should be wide enough for the passage of maintenance equipment. There should be sufficient clearance between the gallery floor and piping to prevent head injuries.

N. Walkways and Storage

Walkways should be provided wherever operators are required to service equipment. Personnel should not have to walk across the grass to reach a tank. Catwalks are useful for servicing motors and other machines located too high for operators to reach.

Adequate storage for spare parts and chemicals is a necessity. Each storage room should have ample floor and shelf storage. Small parts should not lie on the floor or clutter up areas where they can be tripped over. The walls should be designed so that gas bottles can be strapped to them prior to use in order to conserve space.

MAXIMIZING PLANT OPERATIONS FEEDBACK IN THE DESIGN OF WASTEWATER TREATMENT PLANTS

UNIT 3

UNIT 3 - MAXIMIZING PLANT OPERATIONS FEEDBACK IN THE DESIGN OF WASTEWATER TREATMENT PLANTS

OBJECTIVES

At the completion of this presentation the participant shall be able to:

- State the importance of obtaining feedback as a method to enhance quality of design.
- Identify sources of feedback which are available.
- Institute in-house feedback systems which are compatible with the size and nature of the firm.
- Establish a formal in-house review system that maximizes the incorporation of the feedback into reports and designs as they are being produced.
- Produce plant designs that best represent the experience of the firm as a whole.

UNIT 3 - MAXIMIZING PLANT OPERATIONS FEEDBACK IN THE DESIGN OF WASTEWATER TREATMENT PLANTS

I. IMPORTANCE OF FEEDBACK

Incorporating feedback from the operating experience of existing plants into the design of new, expanded or upgraded wastewater treatment plants can greatly improve the new facility's ability to meet its effluent standards. With the generally more stringent effluent requirements imposed by the National Pollutant Discharge Elimination System (NPDES) permits, increased utilization of feedback from previous experiences is a must to provide those features which enhance plant performance and to avoid repetition of previous plant design deficiences which detract from performance.

A common occurrence at many treatment plants is operator criticism of the Design Engineer. This can be largely overcome by gaining feedback from operators so future designs will improve plant operability and flexibility. Plant designs showing concern for operation and maintenance will have the greatest change of meeting effluent criteria on a day-to-day basis and the operator will have a plant with the flexibility to adapt to normal operating problems.

The Design Engineer should make frequent visits to operating plants and plants under construction. The undesirable features of past design concepts can be brought to light in discussions with operators, construction field engineers and start-up personnel. Operators often complain that they rarely see the Design Engineer after plant startup. Operator concerns and client dissatisfaction can be detected, if they exist, by periodic visits and/or communications with the operator after plant startup. These experiences can then be documented in writing and used as a basis for the firm's design policies.

The purpose of a feedback system should be to identify desirable design features as well as to avoid undesirable features. Determination of strong and weak features of plant designs can best be evaluated in light of direct plant operations feedback. Many advances in the state-of-the-art of plant design and equipment features have grown out of suggestions from operators, start-up personnel and resident representatives.

No matter how experienced a design team may be, valuable input can be made by others in the firm to enhance the design. No single project team can hope to be totally versed in all areas of a successful plant design. Input from others in the firm at various stages in the project design, not just in the final phase, can be valuable. Methods to incorporate firm-wide experience include the use of a system of standard technical practices (the extent of which depends on firm size) and the development of a useable storage and

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retrieval system for feedback information. Design reviews by in-house staff members can provide some of the benefits of "value engineering" on projects that may not require formal value engineering analysis.

The proper attention paid to incorporating plant operations feedback not only yields obvious benefits in more effective plant designs but also helps to enhance the reputation of the design firm. Frequently, a less-than-adequate design concept is passed from design to design without its undesirable feature(s) being brought to light. The greatest testimony to a design firm's reputation is an operable and maintainable plant where the operator can meet the effluent criteria over a wide range of operating conditions. In most instances, satisfied operators mean satisfied clients, which means repeat assignments in the future.

II. SOURCES OF FEEDBACK

Perhaps the most valuable single source of feedback from plant operations is information gained during plant startup. The firm's start-up personnel are in the best position to assess the relative operability and maintainability of the plant. Obviously, if the plant has improper hydraulic arrangements, equipment selection, plant layout, lack of operating flexibility, etc., the start-up personnel's job of making the plant run will be that much more difficult. The experiences of start-up personnel should always be passed along directly to the Design Engineers. Periodic seminars for the benefit of Design Engineers, presented by start-up personnel, is time well spent.

A common complaint of operators is that they rarely, if ever, hear from the Design Engineer after final acceptance of the plant by the Owner. It is not uncommon to find an operator who cannot operate his plant optimally because he does not fully understand certain features of the process or equipment operation. Since the Design Engineer will be judged on the effectiveness of the designed plant, it is to his benefit to ensure that the plant operator is well instructed.

Visits to plants designed by other firms are very useful. This is especially true when training inexperienced design personnel. The strong and weak points of other firms' design features can be compared with those of the Design Engineer's firm. Operator preferences can also be determined if the tour leader is an operator. Participation of the firm's start-up and resident representative staff during tours can be invaluable. After such tours, it will become evident to inexperienced personnel that there are numerous ways to achieve the same design goal, and that often several design concepts may achieve the same end but with greatly varying operation and maintenance requirements.

Operator forums can be useful in increasing communication and dialogue between Design Engineers and operators. However, a key factor in ensuring that this is an effective source of feedback is to make sure that the forum is managed to produce constructive criticism and comments. A wealth of constructive feedback can be gained from properly organized operator forums, if cooperation and a spirit of mutual concern can be fostered. The key benefit of operator forums is that both operator and Design Engineer can appreciate the other's perspective. Better future communication should result.

A valuable way to determine undesirable design features is to solicit feedback from resident representatives or field engineers. Frequently the chief operator of the new plant will be involved in inspection of construction, especially during installation of process equipment and plant piping. As a resident representative, the operator is in a position to identify undesirable design features which can be corrected during construction. Valuable additions can be made to the plant operation and maintenance manual from direct representative input. Feedback from resident representatives can help identify manufacturers' representatives who do and do not provide the necessary assistance during equipment installation.

Informing Design Engineers of feedback from plant operations generally is accomplished by means of internal memoranda. These memoranda can be generated from visits to plants, from construction and start-up problems, or from meetings with equipment suppliers. Once design, construction and start-up personnel get in the habit of documenting their experiences, the basis for a feedback system has been established. With the USEPA's current increased emphasis on improving operations and maintenance, as evidenced by today's program, there is an increased awareness by the Design Engineer of features of past designs with suggestions for more effective designs in the future.

III. INCORPORATING FEEDBACK INTO DESIGNS

A starting point in establishing a plant operations feedback system is to determine the firm's guiding policies. The firm that commits itself to a policy of maximum feedback utilization must start by coordinating the efforts of all the individuals involved in plant design, construction and start up. Communication channels and relative priorities should be established. Depending on firm structure (i.e., project group, department and design teams), feedback loops should be set up to effectively function within the existing structure. The key element to establishing a strong feedback system is the full support of the key principals of the firm.

Access to a readily usable system of feedback data is essential to ensure that the data will be used. There are a number of ways to accomplish this, including various filing systems and computer oriented data handling systems. Depending on firm size, this function would be the responsibility of the plant operations staff or members of the design engineering staff. Regardless of the system chosen, the key to success is ready access to the data feedback system so that the information is used in future designs.

An important aspect of an effective design review and feedback system is the selection of key staff members who will be on the review team. Depending on firm size, as shown on Table 3-1, key principals, associates, project engineers, process specialists, operations and maintenance specialists, specification specialists, client representatives, department heads, resident representatives, plant operators and others can comprise the review team. It is desirable to have input from all key areas of design, construction and start up.

TABLE 3-1
DESIGN REVIEW AND FEEDBACK SYSTEM
TYPES OF REVIEW DOCUMENTS AND REVIEW TEAMS

Design Phase	Review Documents	Review Team		
		Small Firm	Medium Firm	Large Firm
Process Evaluation	Influent Loads and Effluent Criteria One-Line Process Flow Diagram Cost-Effectiveness Analysis Basic Design Loadings Operating Features Preliminary Hydraulic Profile Preliminary Site Layout	Key Principals and Project Engineers	Key Principals and Associates Process Specialist Operation and Maintenance Specialist	Key Principles Process Development Department Head Research and Development Department Head Operation and Maintenance Department Head Client's Specialists
Preliminary Design	Complete Process Flow Diagram Operation and Maintenance Concepts Detailed Design Criteria and Sizing Computations Hydraulic Profile Major Equipment List with Methods of Control Final Site Layout Building Interior Layouts Tank Layouts	Key Principals and Project Engineers	Key Principals and Associates Process Specialist Operation and Maintenance Specialist Client Representative	Key Principals Process Development Department Head Operation and Maintenance Department Head Mechanical Department Head Electrical Department Head Architectural Department Head Structural Department Head Construction Department Head Client's Specialists
Detailed Design	Final Plans and Specifications Final Process Flow Diagram and Hydraulic Profile Final Process Design Criteria Documentation of Designer's Operation and Maintenance Intents	Key Principals and Project Engineers Resident Representative Plant Operator (if available)	Key Principals and Associates Process Specialist Operation and Maintenance Specialist Resident Representative Client Representative Plant Operator (if available)	Key Principals Department Heads as Above Operation and Maintenance Representative Resident Representative Client's Specialists Plant Operator (if available)

The development of in-house standards for specifications, design details, design policies and process criteria is a procedure which normally evolves over many years as a firm grows and matures. The ongoing process of establishing, reviewing and updating standards lends itself to inclusion of feedback from plant operations. This is a positive means of incorporating feedback as quickly as possible into the firm's standard operating procedure, without lengthy delays. The firm that maintains a current, readily usable system of design standards embodying plant operations feedback obviously will produce better plant designs.

The firm's management must establish a schedule of milestones in the design process, e.g., process evaluation, preliminary design and detailed design, in which certain documents will be considered by the review team. It is the design team's responsibility to meet the schedule and alert the review team that documents are ready for review. The review procedure should be as flexible as possible to meet the varying needs of routine as well as very complex projects.

A sample of one method of documenting feedback is presented in Attachment 3A. An example of a design review and feedback system is shown in Figure 3-1.

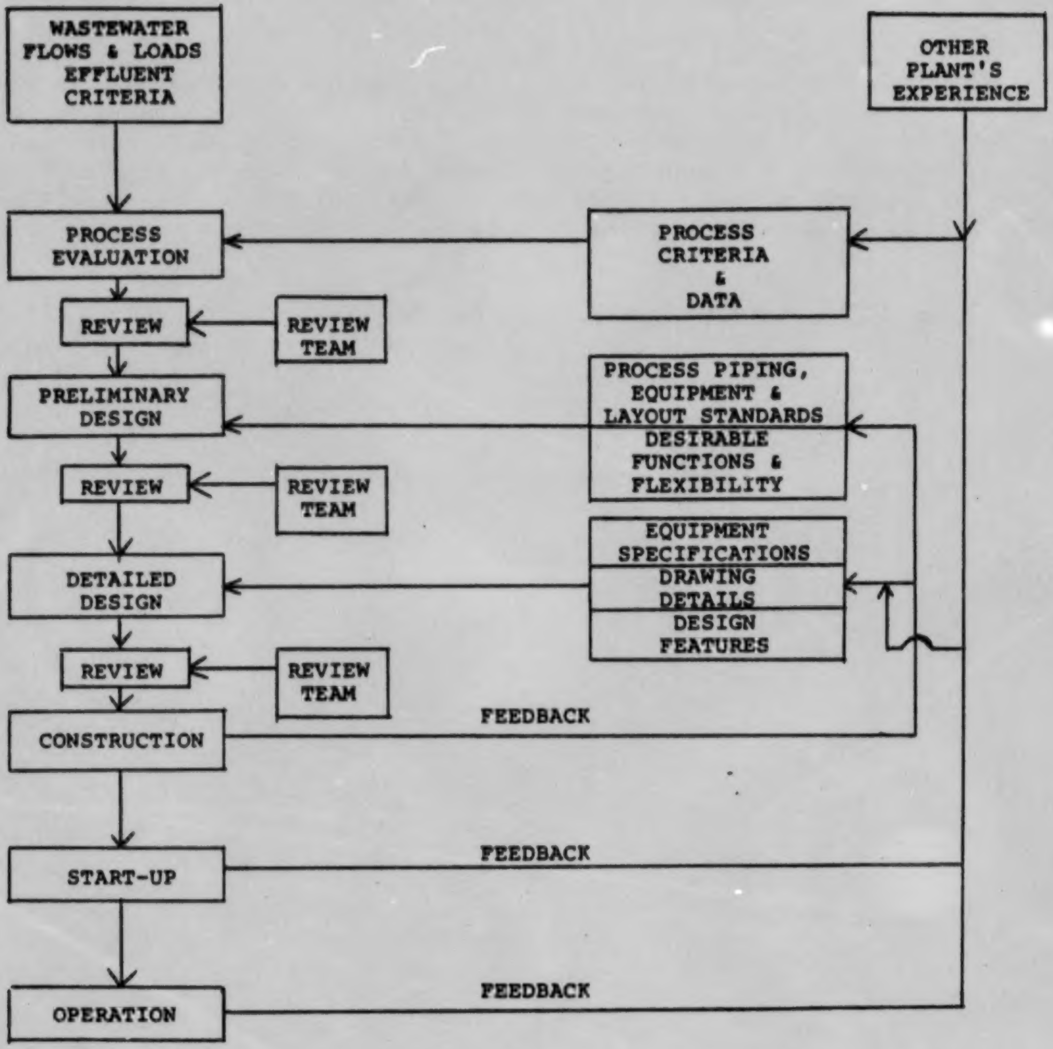
WASTEWATER FLOWS & LOADS EFFLUENT CRITERIA
OTHER PLANT'S EXPERIENCE
PROCESS EVALUATION
PROCESS CRITERIA & DATA
REVIEW
REVIEW TEAM
PRELIMINARY DESIGN
PROCESS PIPING, EQUIPMENT & LAYOUT STANDARDS
DESIRABLE FUNCTIONS & FLEXIBILITY
REVIEW
REVIEW TEAM
EQUIPMENT SPECIFICATIONS
DETAILED DESIGN
DRAWING DETAILS
DESIGN FEATURES
REVIEW
REVIEW TEAM
FEEDBACK
CONSTRUCTION
START-UP
FEEDBACK
OPERATION
FEEDBACK

FIGURE 3.1 DESIGN REVIEW AND FEEDBACK SYSTEM

ATTACHMENT 3A

Sample of Internal Feedback Documentation
Stearns & Wheler
Technical Practice Memorandum

Manual Section No. 2
Memorandum No. 6

Subject: Wastewater Treatment Plant Design

The following have been established as the firm's policies:

1. Solids balances must be prepared for all projects prior to completion of the engineering report. Balances should be prepared for both initial operation and design conditions. Calculations should demonstrate that the frequency and duration of equipment operating cycles is compatible with the solids balance. Special attention should be paid to primary and waste activated sludge pump cycles, sludge storage requirements and methods during off-cycles, such as weekends, sludge dewatering equipment operation times and incinerator operating cycles.

2. The use of mechanical mixers for chlorine mixing upstream of chlorine contact tanks is most desirable. Serpentine baffles in contact tanks can be eliminated if a mixer is used, but an influent baffle or open block wall is desirable to distribute the flow uniformly throughout the tank cross section to avoid short circuiting.

   The tops of baffle walls should be located slightly (1 inch +) below the water surface to allow scum to float to the scum baffle.

3. All tanks should be provided with a positive means of draining, preferably by a gravity piped drain system. Sumps should be provided for all tanks, whether or not piped drains can be installed. Rectangular tank floors should be pitched toward the side or end of the tank at which the sump is located. Sump size should be at least 18 inches square by 18 inches deep. Gutters along one side of the tank should be used to facilitate hosing and drainage of sludge deposits.

4. Chlorine room doors should be wide enough to allow ton containers to pass through without damaging the doors. An 8-foot double door is desirable. Hoists for 1-ton containers should be high enough to allow lifting of one container over another, including allowances for floor chocks, lifting yoke, hook and hoist mechanism.

5. When an interior vision panel is provided in a chlorine room, a 3-way light switch should be located adjacent to the outside of the vision panel to allow inspection of the room without entering.

6. Chlorine room ventilation systems should be designed to:

   a. Avoid any ventilating interconnections with any other rooms.

   b. Avoid negative pressure in the room. Negative pressure may make it very difficult to open the door in case of the need for a quick departure when a chlorine leak occurs.

   c. Exhaust air from the room floor-chlorine gas is heavier than air.

   d. Avoid discharging exhaust air near another building's air intake, escape route, or similar area of concern.

7. For hosing down operating areas, the following should be provided:

   a. 1-1/2 inch hose bibs for occasional heavy-duty cleaning. Hose need not be provided for every bib.

   b. 3/4-inch hose bibs for normal housekeeping with a liberal supply of hoses and nozzles. These should be provided on both plant effluent systems and on non-potable fresh water systems.

   c. Hose bibs for potable water should have back-siphonage check valves.

8. Because treatment plants are usually located at low elevations, water pressures in the municipal system may be high enough to cause severe water hammer. During design, the available pressure should be checked and, if too high (75 psi +), a pressure reducing valve should be provided.

9. Vacuum filter installations should:

   a. Be equipped with variable agitator speed.

   b. Have a hot water connection to the media wash piping.

   c. Have a water supply connected to all chemical piping to permit regular flushing.

10. Rectangular collector drives serving more than one tank should be equipped with jaw clutches to allow disengagement of the drive in one tank without having to stop the other.

11. Chlorine solution should be piped to thickener influent piping for odor control and to return sludge piping for bulking control. A dosage of 50 mg/l is suggested. Each chlorine solution branch should have a rotometer and flow control valve.

12. Separate effluent pumps for chlorine solution water should be provided, unless water is supplied from the municipal system. Generously sized basket-type strainers should be used on effluent water reuse systems.

13. Influent baffles in rectangular secondary settling tanks should be 1/2 to 2/3 tank depth.

PLANS AND SPECIFICATIONS REVIEWS

UNIT 4

UNIT 4 - PLANS AND SPECIFICATIONS REVIEWS

OBJECTIVES

At the conclusion of the presentation of this unit the participant shall be able to apply various techniques when reviewing plans and specifications.

- He will be able to list the subject matters that will be required to be included in an Engineer's Report.
- He will be able to name several standard guides by which he may properly prepare the Engineer's Report for the plan and specification review process.
- He will be able to utilize the guides in his own environment.
- He will be able to prepare plant plans in formats that will facilitate the review process.
- He will be able to prepare plant specifications with a completeness that will benefit the builder in the construction of the best possible plant.
- He will be able to prepare revisions to approved plans using proper procedures.
- He will be able to specify procedures which will keep the existing plant operating during the construction period.
- He will be able to delineate control measures to minimize erosion during construction.

UNIT 4 - PLANS AND SPECIFICATIONS REVIEWS

I. INTRODUCTION

In designing a wastewater treatment plant, the Design Engineer must always keep in mind the review process by which the plant plans and specifications will be evaluated. Very early in the design process he should familiarize himself thoroughly with the regulations, policies and standards that the plans and specifications must meet and by which they will be evaluated. Included in these policies are Federal requirements that apply to the development of engineering reports, plans and specifications.

While the exact syllabus for plans and specifications reviews will be determined for each individual wastewater plant, there are several guides that are commonly used. This unit is taken from the "Guides for the Design of Wastewater Treatment Works," 1980 Edition, prepared by the Technical Advisory Board of the New England Interstate Water Pollution Control Commission. These Guides, in form, adopt many of the standards published by the Great Lakes--Upper Mississippi River Board of State Sanitary Engineers (Ten-State Standards, 1978 Edition).

All reports, plans and specifications should be submitted at least 60 days prior to the date upon which action by the approving authority is desired. The documents submitted for formal approval shall include the engineer's report, plans and specifications. It is suggested that preliminary plans be submitted with the engineer's report for review prior to the preparation of final plans. However, no approval for construction can be issued until final, detailed plans and specifications have been submitted to the approving authority and found to be satisfactory.

II. ENGINEER'S REPORT

The purpose of the report is to present in clear, concise form a description of the problem; alternative solutions examined, rejected and recommended; their technical and financial feasibility; and their environmental impact. The report should be written for easy public understanding, and serve as a convenient and permanent summary of the principle information needed by regulatory and funding agencies to support the recommended project. Controlling assumptions made and factors used in the functional design of systems should be summarized for convenient and permanent reference. Data on structural, mechanical and electrical designs may be excluded except to the extent that reference to such elements is necessary in checking the functional operation.

A. General

An engineer's report shall be submitted which will include as much of the following data on sewers, pumping stations and wastewater treatment works as pertain to the project.

- Brief description of project including statement of need.
- Classifications of waters, permits, orders of State agencies, etc.: Set forth briefly pertinent data regarding relevant permits, orders, etc., issued by the approving authority.
- Location: Describe geographic location of municipality and of project, with any necessary reference to maps or exhibits. Give specific locations of existing and proposed pumping stations and wastewater treatment works.
- Topography: Briefly describe topography and include contour map of the general area with specific reference to the area involved in the project.
- Population: Set forth past census data and estimated future growth for the municipality or population involved in the proposed project, whichever is applicable.
- Water Supply: Discuss the location of intake, springs or wells, treatment plants, reservoirs, watersheds or other features of public health significance with relation to various portions of the systems. Discuss potential or planned improvements which would impact future water use or wastewater flow projections.
- Garbage Disposal: Describe present methods of garbage disposal and discuss the possibility of the future disposal of garbage wastes with wastewater.
- Field Survey Data
  - Volume and Strength of Wastewater Flow: Where there are existing sewers, the volume and strength of wastewater flow shall be determined. The designing engineer shall confer with the reviewing agency to establish the scope of the data necessary. These data shall be obtained from actual flow measurements; preferably during both wet and dry weather periods. If a public supply is already in use, give approximate maximum, minimum, and average daily water consumption and, where appropriate, analysis of water as it might affect the character of the wastewater. Laboratory analyses should be made on samples collected with consideration of quality variations in a 24-hour period. These data should include composite samples for the maximum significant period of sewage and industrial waste discharge and should cover a sufficient period of time to be

representative of actual conditions. The designing engineer shall confer with the reviewing agency for details concerning the collection and analysis of samples.

- ° ° Industrial Wastes: List all establishments producing industrial wastes and give quantity, producing periods, and character of industrial wastes insofar as they may affect the sewer system or wastewater treatment works. Quantity and character of wastes shall be based on flow gauging and laboratory analysis of composite samples. In major metropolitan areas where discrete sampling of each industry is not feasible, a composite analysis of several industries may be used. Discuss the characteristics and volume of industrial wastes for the foreseeable future.

- ° ° Septic Tank Cleanings: Indicate expected amounts of septic tank cleanings tributary to the system, and their seasonal variations.

- ° ° Soil Investigations and Core Borings: Indicate extent of investigations regarding these subjects, including information on rock likely to be encountered. Discuss any unusual foundation conditions. Indicate portion of project below high ground water level. Include a summary of borings made, their depth, depth to ledge and ground water, nature of soil encountered, and a map locating the borings.

- ° ° Infiltration/Inflow: The quantity of infilitration/inflow shall be measured in existing sewer systems and a comparison made to determine if the infilitration/inflow can be most economically eliminated by reconstruction or repair of the sewer system, or treated at the proposed plant.

- ° ° Flooding: If any part or parts of the project will be subject to upland or tidal flooding of a 100-year or less frequency, discuss the extent and effects of such flooding. Discussions should include abnormally high water caused by ice jams. State what precautions against flooding are incorporated in the design, with respect to flooding of the sewer collection system, pump stations and treatment plant.

B. Individual Systems

For small communities, the report should assess the ability of abating existing pollution, health hazards and nuisance conditions by construction of individual or small group subsurface disposal systems; their technical feasibility, past effectiveness and limitations, if any, on other community development plans.

- ° Local Soil Conditions: The report should discuss acceptability of local housing density, water supplies, soil and ground water conditions to individual subsurface wastewater disposal. Where such systems are feasible, the results of detailed soils investigations should be presented. Where not feasible, a concise explanation of the salient reasons, together with pertinent soils data, should be presented.

- Reliability: The report should discuss the continued reliability of individual systems where soil conditions are marginal in all or part of the service area.

- Municipal Management: The report should discuss the feasibility of municipal management of septage disposal and septage pumping to insure long useful lives of individual systems if adopted.

C. Land Treatment and Disposal

The report shall assess the technical and financial feasibility of land treatment and disposal systems. For projects receiving federal funds, the report shall comply with the most recent EPA requirements on evaluation of land application.

- Summary Survey of Alternative Sites: The report should present a summary survey of alternative land treatment and disposal sites considered and briefly state the reasons for rejecting the least favorable ones. The most favorable sites should be studied in depth and a thorough exposition of technical and financial feasibility presented in the report.

- Required Land Area and Location: The report shall present a detailed discussion of land treatment and disposal at the most favorable areas including a definition of required land area, soil characteristics, local impact on growth patterns, agriculture, elimination of the property tax rolls, and any other applicable positive or negative effects.

- Required Pretreatment: The report shall discuss the required pretreatment of wastes prior to land treatment and/or disposal, together with such influencing factors as industrial waste present, seasonal variations in waste flow and character, and combined storm and sanitary flow.

- Agricultural Benefit: The report shall present any positive or negative agricultural effects which may arise through land treatment and disposal practices such as nutrient benefits, heavy metal contamination, land reclamation and potential financial returns on cash crops.

D. Innovative/Alternative Technology

The report shall discuss opportunities for use of innovative or alternative technology and their application to the project or components of the project. Where such measures have feasible application, the report shall include a discussion of their financial impact, reliability, impact on planned municipal, industrial and commercial growth, anticipated useful life, and other pertinent factors.

- Examples of alternative systems include proven techniques for reclaiming or reuse of wastewater or sludges, land treatment, aquifer recharge, industrial reuse, reclamation of disturbed land, agricultural uses, composting, revegetation, and energy recovery systems based upon sludge and refuse disposal.

- Examples of innovative systems include developed processes and techniques which are not fully proven in the context of their contemplated use, but which may promote increased energy conservation or reuse, greater recycling and conservation of water resources, improved efficiency and reliability, better management of toxics, greater beneficial use of sludges and/or other environmental benefits.

- Where such systems are found desirable technically, financially and environmentally, the report should clearly explain any risks the municipality may assume by adoption of these systems. Such risks might include imprecise knowledge of their useful life, high dependency upon the diligence and skill of lay operators to achieve satisfactory operation, or the requirement for substantial capital investments in the event of failure.

E. Water Conservation

The report shall include a discussion of alternative flow and waste reduction measures which can be taken by the municipality and individuals. Such measures may include public education, installation of water meters, amendment of local building codes to require low flow fixtures, retrofit of existing buildings to low flow fixtures or other pricing and regulatory actions or combinations of these.

- Where such measures are determined feasible, the report shall present an estimate of the immediate and future waste flow reduction, and the cost implications of such actions including non-project costs or savings to individuals and project costs or savings.

F. Wastewater Treatment Works

For wastewater treatment works, the engineer's report shall include this additional information:

- Description of Contributory Areas:

  - Briefly describe the extent of the existing and proposed contributory areas to the proposed wastewater treatment works with reference to a map or exhibit.

  - Describe the areas of probable future expansion of the sewer system contributory to the wastewater treatment works. Discuss any factors which may affect future changes in population.
  - Describe the location of the wastewater treatment works and point of discharge with reference to the contributing sewer system.
  - Describe present and proposed methods of treatment and disposal of septic tank cleanings.

- Site: Discuss the various sites available and the reasons for choosing the one recommended. Indicate the proximity of residences or developed areas to any treatment works, and discuss the accessibility of the plant site. Include a sketch of the property to be used for the treatment works, on which shall be indicated the topography and the arrangement of present and future treatment units.
- Type of Process: Discuss the type of treatment processes studied and the reasons for choosing the recommended alternative. Include considerations of treating industrial flows, septage loading, ability to take shock loads from failing industrial pretreatment systems, ease of operation, energy consumption, capital and operating cost, level of operator's skill and effort required, and expansion ability.
- Brief Description of Existing Plant (if any): Discuss limitations of plant or of individual units that require additions, modifications or expansions.
- Basis of Design of the Recomended Alternative:
  - Design period.
  - Design Population Total: Indicate resident and non-resident sewered and unsewered population and industrial wastes population equivalent where appropriate.
  - Strength of Wastewater: Indicate BOD and suspended solids (mg/l and/or lbs./day) for domestic wastewater and for industrial wastes. Allowances should be made for contributions from septic tank cleanout wastes. Other wastewater constituents should be listed as appropriate, e.g., nitrogen, phosphorus, metals, organic chemicals, temperature, chlorides, color, fibers and pH.
  - Total Wastewater Flows: Indicate per capita and total daily flow, infiltration allowance and storm water.

  - Initial and Design Flow Rate: Indicate minimum, average and maximum flow rates both for the 24-hour period and for the maximum hourly period for both wet and dry weather conditions. Peak instantaneous wet and dry weather flows should be given.

  - Treatment Units: Describe the major units of the wastewater treatment works giving their capacities, sizes, equipment, and operation factors under varying conditions and methods of operation, including emergencies and major maintenance periods.

- Receiving Body of Water: Name and describe the watercourse or body of water into which the final effluent is to discharge. Describe its condition, classification and uses. If a stream, give the low flow determined in accordance with the method used by the reviewing agency concerned.

G. Recommendations

Outline recommendations in detail concerning the proposed works and future expansion thereof, as follows:

- Alternate Plans: Where two or more solutions exist for a particular problem, each of which is feasible and practical, discuss the several solutions and reasons for selecting the one recommended.

- Sewer System: Describe the area and extent to which plans provide sewerage facilities for future development. If the area to be served by existing and proposed sewers does not include the entire municipality or natural drainage area, a brief description should be given of that portion not included, together with information as to the probability of future development, and how this area can be served. A sketch should be provided.

- Wastewater Treatment: Discuss the degree and type of treatment, reasons for adopting the proposed method, and adequacy for present and future needs. New methods or processes should be fully described. A general layout and quantitative flow diagram should be provided.

- Financing: Give estimated cost of integral parts of the system for the contemplated installation and a detailed estimated annual cost of operation. Give a summary of the anticipated means of financing the total project cost including estimates of state, federal and local monies required. Where applicable, information should include: existing policies, obligations or commitments bearing on financing of proposed sewers, amounts and retirement schedule of outstanding bonds, unobligated bonding capacity available for proposed project, taxable valuations, existing tax levies and any limits affecting proposed project; and aschedule of existing sewer service rates and the revenue yielded by them. Special methods of spreading assessments should be explained. A clear concise summary of the total annual cost to the community and to typical users of the project based on one or more alternative financing plans should be given in the report.

- Industrial Wastes: Where it is necessary to provide preliminary treatment of industrial wastes or where they are of such a character that they should be excluded from the sewers, pertinent information shall be provided. The engineer should recommend to the municipality the adoption of an ordinance regulating the discharge of industrial wastes that might adversely affect the wastewater works or their operation.

III. PLANS

A. General

All plans for treatment works shall bear a suitable title showing the name of the municipality, sewer district or institution; and shall show the scale in feet, a graphical scale, the north point, a date, and the name of the engineer and imprint of his registration seal.

The plans shall be clear and legible. They shall be drawn to a scale which will permit all necessary information to be plainly shown. The size of the plans generally should not be larger than 24 inches by 36 inches. Datum used and its relation to mean sea level datum (USC 7 GS) should be indicated. Locations and logs of test borings, when made, shall be shown on the plans.

Detail plans shall consist of plan views, elevations, sections and supplementary views which, together with the specifications and general layouts, provide the working information for the contract and construction of the works. Include dimensions and relative elevations of structures, the location and outline form of equipment, location and size of piping, water levels and ground elevations.

B. Plans of Wastewater Treatment Plants

- Location Plan: A plan shall be submitted, showing the wastewater treatment plant in relation to the remainder of the system. Sufficient topographic features shall be included to indicate its location with relation to streams and the point of discharge of treated effluent.

- General Layout: Layouts of the proposed wastewater treatment plant shall be submitted, showing:

    - Topography of the site.

    - Size and location of plant structures.

  - Schematic flow diagram showing the flow through various plant units.
  - Piping, including any arrangements for by-passing individual units. Materials handled and direction of flow through pipes shall be shown.
  - Hydraulic profiles showing the flow of wastewater, supernatant liquor and sludge.
  - Test borings and ground water elevations.

- Detail Plans: Detail plans shall show the following:
  - Location, dimensions and elevations of all existing and proposed plant facilities.
  - Elevations of high and low water level of the body of water to which the plant effluent is to be discharged.
  - Type, size, pertinent features and manufacturer's rated capacity of all pumps, blowers, motors and other mechanical devices.
  - Complete schematic diagrams for all sludge and chemical piping systems.
  - Minimum, average and maximum hydraulic flow in profile.
  - Adequate description of any features not otherwise covered by specifications.
- Laboratory Facilities: the plan shall include such laboratory facilities as are necessary to perform analyses required by the State regulatory agency.

IV. SPECIFICATIONS

Complete technical specifications for the construction of sewers, wastewater pumping stations, treatment plants and all appurtenances, shall accompany the plans.

The specifications accompanying construction drawings shall include, but not be limited to, all construction information not shown on the drawings which is necessary to inform the builder in detail of the design requirements as to the quality of materials, workmanship and fabrication of the project. They shall also include: the type, size, strength, operating characteristics and rating of equipment; allowable infiltration including allowable methods of measuring infiltration; the complete requirements for all mechanical and electrical apparatus, wiring, and meters; laboratory fixtures and equipment; operating tools; construction materials; special filter materials such as stone, sand or gravel; installation specifications for sewers; miscellaneous equipment as necessary to meet design standards; and operating tests for the completed works and component units.

V. REVISIONS TO APPROVED PLANS

Any deviations from approved plans or specifications shall be approved in writing before such changes are made. Plans or specifications so revised should, therefore, be submitted well in advance of any construction work which will be affected by such changes, to permit sufficient time for review and approval. "As built" plans clearly showing such alterations should be submitted to the reviewing agency at the completion of the work.

VI. OPERATION DURING CONSTRUCTION

Specifications shall contain a program for keeping existing treatment plant units in operation during construction of plant additions. Should it be necessary to take plant units out of operation, a shutdown schedule agreed to by the State agency shall be adhered to and shall minimize pollutional effects on the receiving waters.

VII. EROSION CONTROL PLAN

The plans and specifications should delineate what measures are to be taken by the contractor to minimize erosion during the construction period.

UNIT 5 - GENERAL DESIGN CONSIDERATIONS

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- List four site factors to be considered in system location and layout.
- Explain why "type of treatment" is an important locational factor.
- List five factors which must be considered when designing for flexibility and reliability.
- Identify proper and improper design of materials and equipment handling facilities.
- Discuss from memory various maintenance considerations which have an effect on plant layout.
- Discuss the pros and cons of the use of automation at a given facility.

UNIT 5 - GENERAL DESIGN CONSIDERATIONS

A. System Location and Layout

There are several factors that must be considered when selecting the location and layout of a wastewater treatment plant. Site constraints such as the availability of land, environmental restrictions and natural limitations can dictate the location of a plant and the arrangement of unit operations within the facility. The location of a treatment plant will also be influenced by the type of development in the immediate vicinity. When possible, it is best to locate a facility as far from the centers of urban growth as is reasonable. Additionally, buffer zones preventing encroachment of residential development on the site are desirable. These buffers may include industrial parks, large highways, golf courses and railroad tracks (see Figure 5.1). The influence of the surrounding community can affect both the plant layout and design (e.g., whether or not certain odor controls have to be instigated) and the type of treatment methods used (e.g., whether waste sludge can be applied to soil or if the sludge must be hauled off).

The type of treatment chosen to meet effluent requirements will influence the choice of a site and the general system layout. For example, land application of treated effluent or sludge will necessitate a sufficient amount of appropriate soil for the purpose, and some sort of buffer from the population being served. If the plant is to continue to meet effluent requirements as the community it serves grows, the initial layout must be flexible enough to allow for future expansion. The treatment system needs the flexibility to be upgraded should there be future revised discharge requirements that call for more restrictive effluent standards (see Figures 5.2, 5.3, 5.4 and 5.5).

The selection of unit process alternatives will determine the complexity of plant operation. In small plants, it is desirable to minimize the number of unit operations that must be managed. A common practice is to eliminate the use of primary settling tanks and to use aerobic digesters. Another technique is to use sludge drying beds instead of mechanical dewatering equipment. However, in northern climates, stabilized sludge must be stored during periods when the drying beds are not operable. Many small extended-aeration facilities do not have this capability.

Unit processes should be arranged so as to facilitate treatment plant operation. In small and medium plants, it may be possible to arrange components around a centrally located operations building. This would allow use of the basement of the building for primary and secondary sludge pumps, aeration blowers and thickened or digested sludge pumps. The upper floor of the building could house vacuum filtration equipment as well as office, laboratory, locker, storage and chlorination equipment. In large plants,

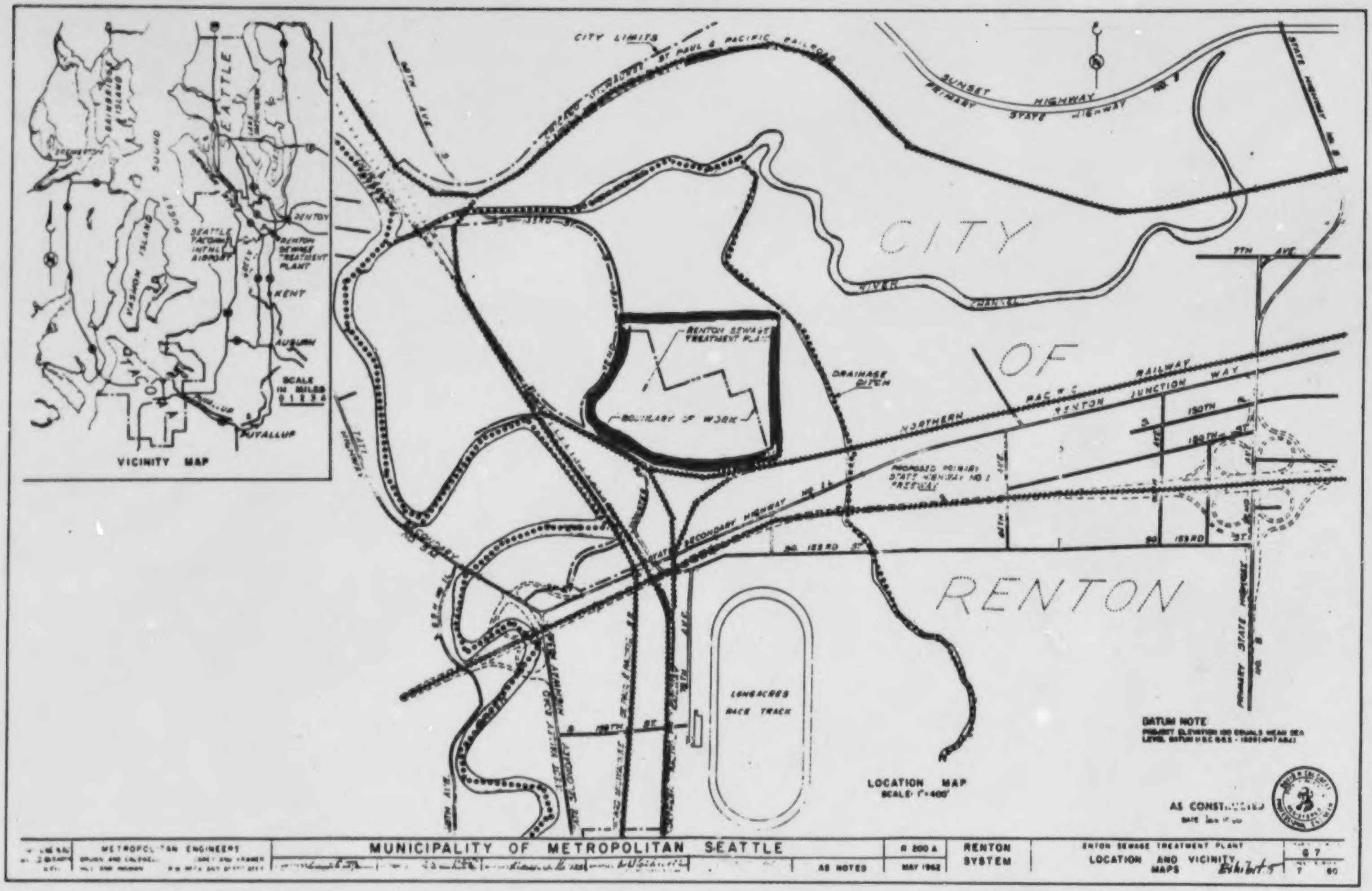
CITY LIMITS
ST PAUL & PACIFIC RAILROAD
SUNSET HIGHWAY
PRIMARY STATE HIGHWAY NO. 2
CITY
OF
RENTON
RIVER
CHANNEL
7TH AVE
RENTON SEWAGE TREATMENT PLANT
BOUNDARY OF WORK
DRAINAGE DITCH
NORTHERN PACIFIC RAILWAY
RENTON JUNCTION WAY
PROPOSED PRIMARY STATE HIGHWAY NO. 1 FREEWAY
SECONDARY HIGHWAY
153RD ST
156TH ST
158TH ST
LONGACRES RACE TRACK
DATUM NOTE
LOCATION MAP
SCALE: 1"=400'
AS CONSTRUCTED
VICINITY MAP
SEATTLE
SOUND
BAINBRIDGE ISLAND
VASHON ISLAND
SEATTLE TACOMA INTNL AIRPORT
RENTON
RENTON SEWAGE TREATMENT PLANT
KENT
AUBURN
TACOMA
PUYALLUP
SCALE IN MILES
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
AS NOTED
MAY 1962
RENTON SYSTEM
RENTON SEWAGE TREATMENT PLANT
LOCATION AND VICINITY MAPS

FIGURE 5.1 BUFFER ZONES AROUND THE RENTON SEWAGE TREATMENT PLANT

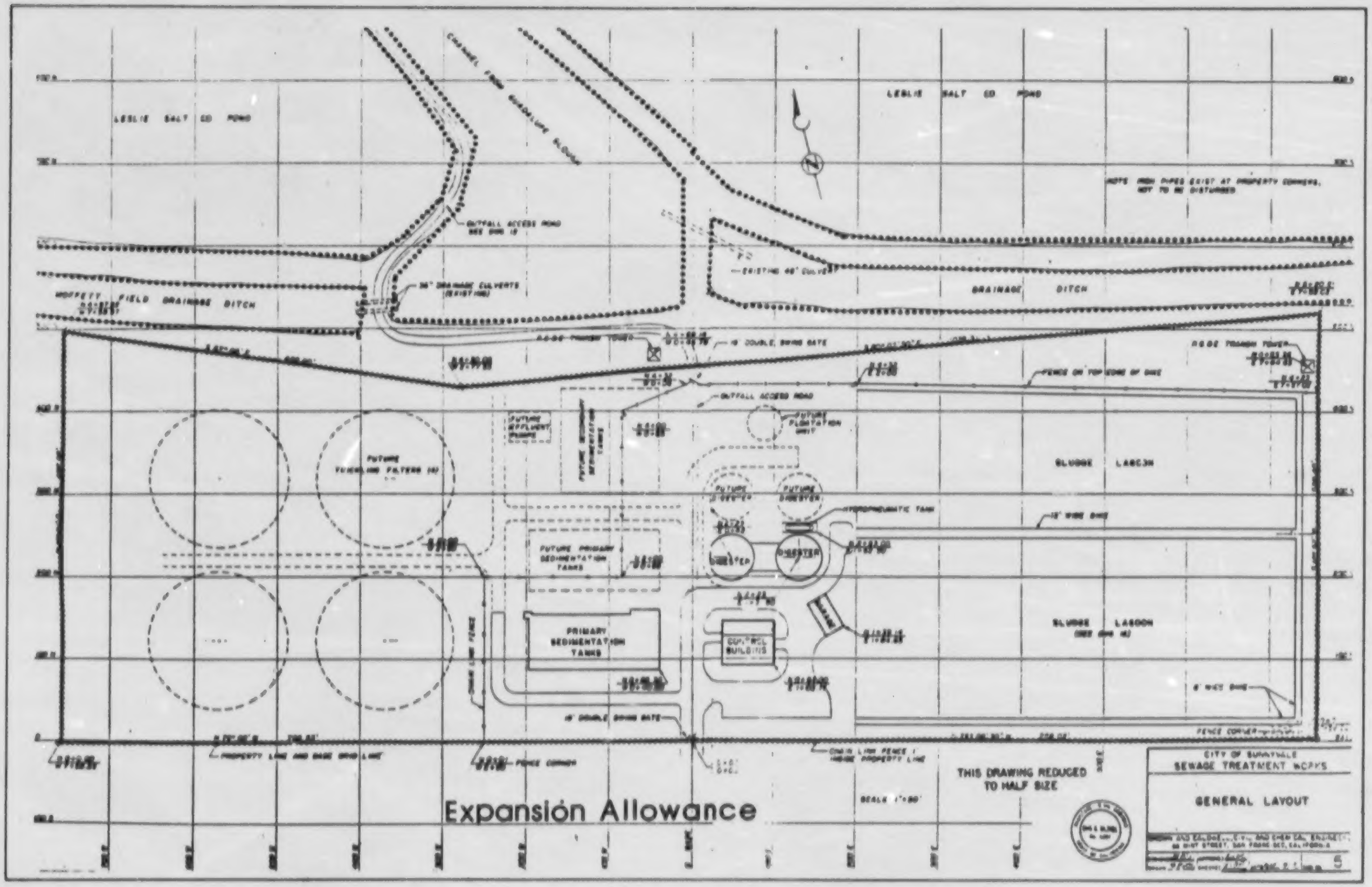
LESLIE SALT CO POND
LESLIE SALT CO POND
CHANNEL FROM GUADALUPE SLOUGH
NOTE: IRON PIPES EXIST AT PROPERTY CORNERS, NOT TO BE DISTURBED
OUTFALL ACCESS ROAD
36" DRAINAGE CULVERTS (EXISTING)
EXISTING 48" CULVERT
MOFFETT FIELD DRAINAGE DITCH
DRAINAGE DITCH
P.G.&E. TRANSM. TOWER
16' DOUBLE SWING GATE
P.G.&E. TRANSM. TOWER
FENCE ON TOP EDGE OF DIKE
OUTFALL ACCESS ROAD
FUTURE EFFLUENT PUMPS
FUTURE SECONDARY SEDIMENTATION TANKS
FUTURE FLOTATION UNIT
FUTURE TRICKLING FILTERS
FUTURE DIGESTER
FUTURE DIGESTER
HYDROPNEUMATIC TANK
SLUDGE LAGOON
12' WIDE DIKE
FUTURE PRIMARY SEDIMENTATION TANKS
DIGESTER
DIGESTER
PRIMARY SEDIMENTATION TANKS
CONTROL BUILDING
SLUDGE LAGOON
8' WIDE DIKE
16' DOUBLE SWING GATE
FENCE CORNER
PROPERTY LINE AND BASE GRID LINE
FENCE CORNER
CHAIN LINK FENCE INSIDE PROPERTY LINE
THIS DRAWING REDUCED TO HALF SIZE
SCALE 1"=50'
Expansión Allowance
CITY OF SUNNYVALE
SEWAGE TREATMENT WORKS
GENERAL LAYOUT
5

FIGURE 5.2 EXPANSION ALLOWANCE FOR ADVANCED TREATMENT FACILITIES

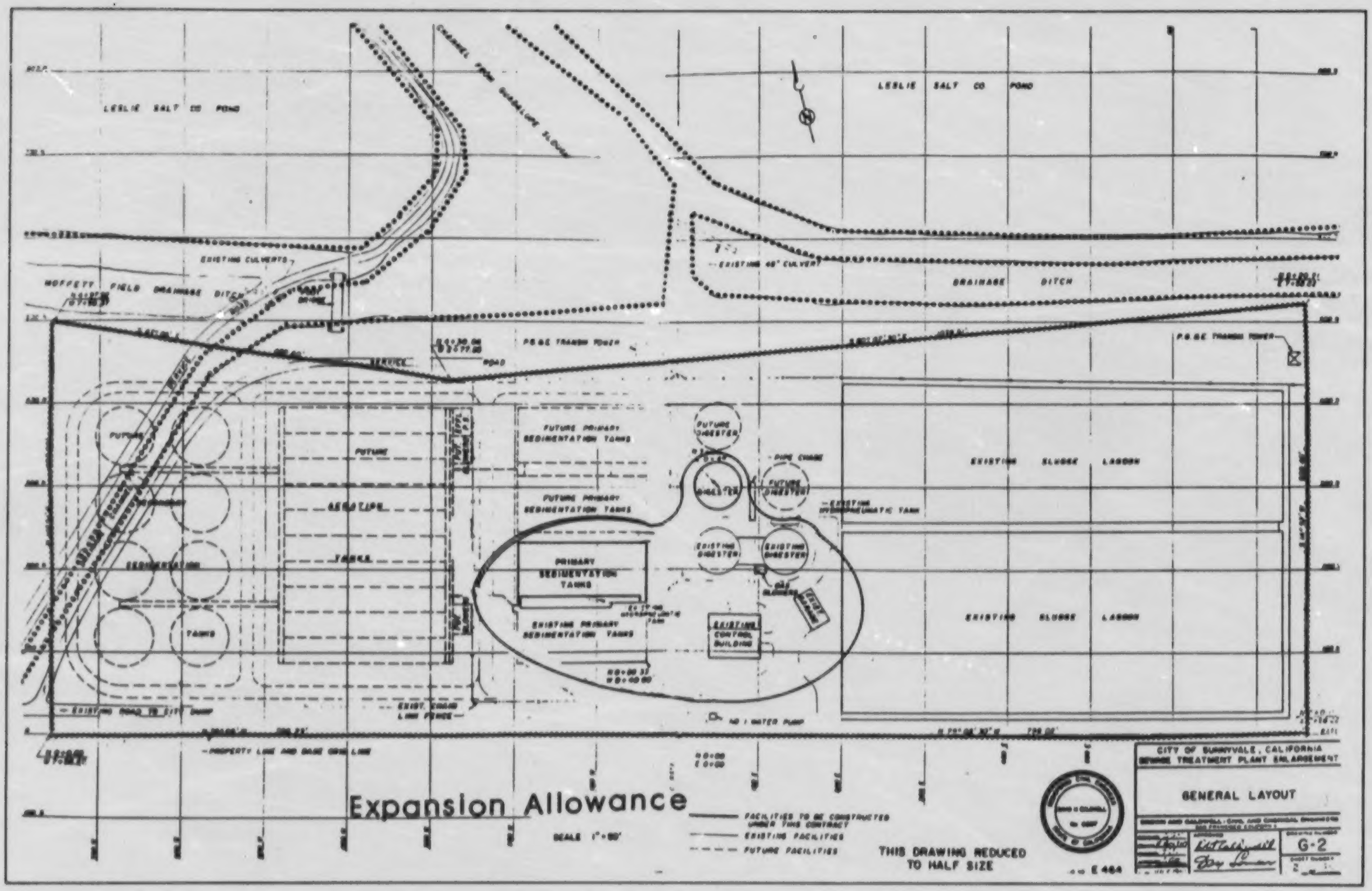
LESLIE SALT CO POND
CHANNEL FROM GUADALUPE SLOUGH
LESLIE SALT CO POND
EXISTING CULVERTS
MOFFETT FIELD DRAINAGE DITCH
EXISTING 48" CULVERT
DRAINAGE DITCH
P.G.&E. TRANSM. TOWER
SERVICE ROAD
P.G.&E. TRANSM. TOWER
FUTURE
FUTURE
EXISTING
TANKS
SEDIMENTATION
TANKS
FUTURE PRIMARY SEDIMENTATION TANKS
FUTURE PRIMARY SEDIMENTATION TANKS
PRIMARY SEDIMENTATION TANKS
EXISTING PRIMARY SEDIMENTATION TANKS
FUTURE DIGESTER
DIGESTER
FUTURE DIGESTER
PIPE CHASE
EXISTING HYDROPNEUMATIC TANK
EXISTING DIGESTER
EXISTING DIGESTER
GAS BLOWERS
EXISTING CONTROL BUILDING
EXISTING SLUDGE LAGOON
EXISTING SLUDGE LAGOON
EXISTING ROAD TO CITY DUMP
EXIST. CHAIN LINK FENCE
NO. 1 WATER PUMP
PROPERTY LINE AND BASE GRID LINE
N 0+00
E 0+00
Expansion Allowance
SCALE 1"=50'
FACILITIES TO BE CONSTRUCTED UNDER THIS CONTRACT
EXISTING FACILITIES
FUTURE FACILITIES
THIS DRAWING REDUCED TO HALF SIZE
E 464
CITY OF SUNNYVALE, CALIFORNIA
SEWAGE TREATMENT PLANT ENLARGEMENT
GENERAL LAYOUT
G-2

FIGURE 5.3 EXPANSION ALLOWANCE FOR INCREASED CAPACITY

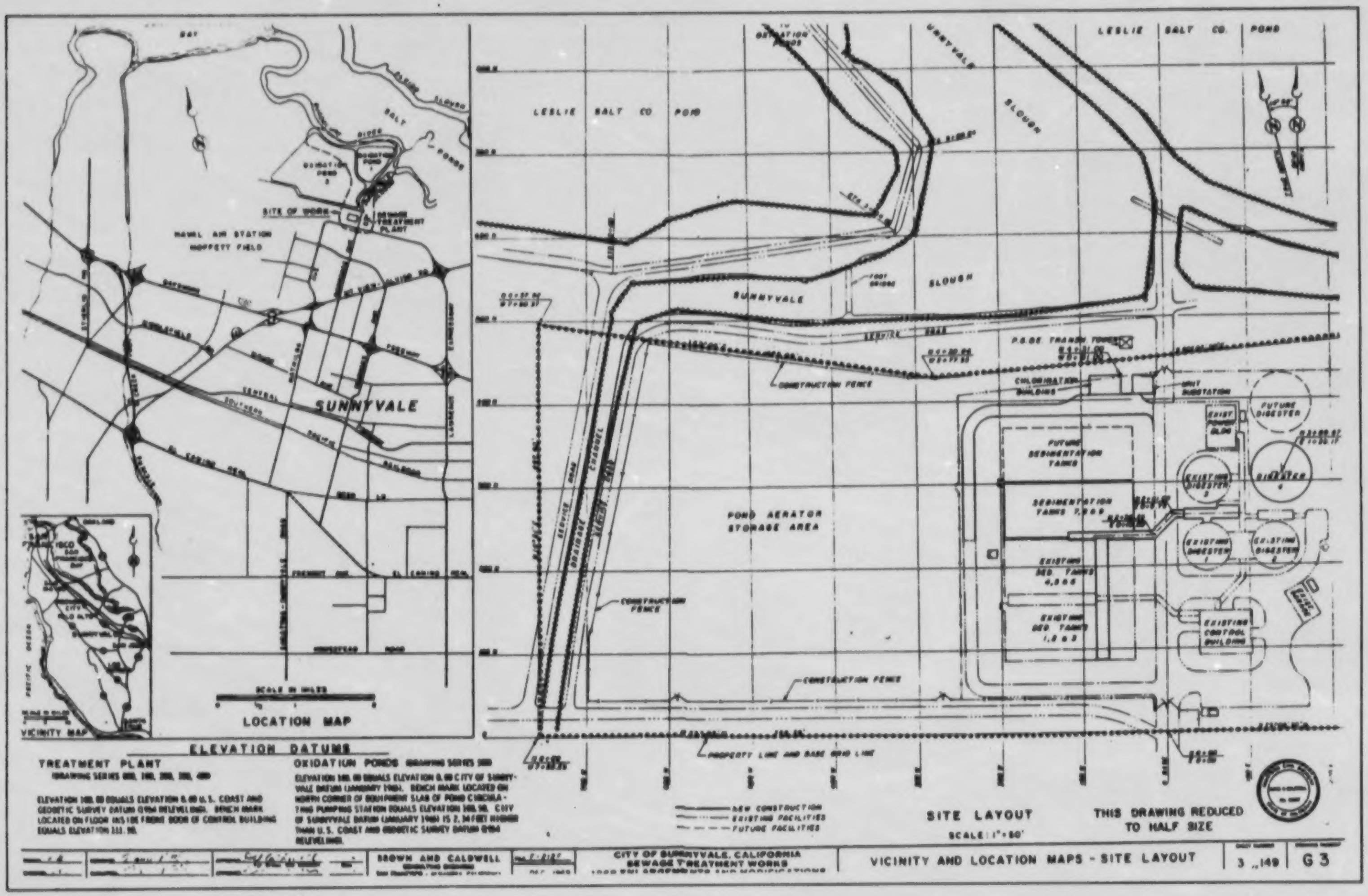
BAY
SALT PONDS
SITE OF WORK
SEWAGE TREATMENT PLANT
NAVAL AIR STATION MOFFETT FIELD
SUNNYVALE
EL CAMINO REAL
FREMONT AVE
HOMESTEAD ROAD
SCALE IN MILES
LOCATION MAP
VICINITY MAP
PACIFIC OCEAN
LESLIE SALT CO. POND
SUNNYVALE SLOUGH
SERVICE ROAD
CONSTRUCTION FENCE
P.G.&E. TRANSM TOWER
CHLORINATION BUILDING
SUBSTATION
FUTURE DIGESTER
DIGESTER 4
EXISTING DIGESTER 3
EXISTING DIGESTER 1
EXISTING DIGESTER 2
FUTURE SEDIMENTATION TANKS
SEDIMENTATION TANKS 7, 8 & 9
EXISTING SED. TANKS 4, 5 & 6
EXISTING SED. TANKS 1, 2 & 3
EXISTING CONTROL BUILDING
POND AERATOR STORAGE AREA
DRAINAGE CHANNEL
PROPERTY LINE AND BASE GRID LINE
ELEVATION DATUMS
TREATMENT PLANT
DRAWING SERIES 000, 100, 200, 300, 400
ELEVATION 100.00 EQUALS ELEVATION 8.00 U.S. COAST AND GEODETIC SURVEY DATUM 1956 RELEVELING. BENCH MARK LOCATED ON FLOOR INSIDE FRONT DOOR OF CONTROL BUILDING EQUALS ELEVATION 111.90.
OXIDATION PONDS DRAWING SERIES 500
ELEVATION 100.00 EQUALS ELEVATION 8.00 CITY OF SUNNYVALE DATUM (JANUARY 1960). BENCH MARK LOCATED ON NORTH CORNER OF EQUIPMENT SLAB OF POND CIRCULATING PUMPING STATION EQUALS ELEVATION 108.50. CITY OF SUNNYVALE DATUM (JANUARY 1960) IS 2.34 FEET HIGHER THAN U.S. COAST AND GEODETIC SURVEY DATUM 1956 RELEVELING.
NEW CONSTRUCTION
EXISTING FACILITIES
FUTURE FACILITIES
SITE LAYOUT
SCALE: 1" = 80'
THIS DRAWING REDUCED TO HALF SIZE
BROWN AND CALDWELL
CITY OF SUNNYVALE, CALIFORNIA
SEWAGE TREATMENT WORKS
VICINITY AND LOCATION MAPS - SITE LAYOUT
3 ,,149
G 3

FIGURE 5.4 INTERIM USE OF EXPANSION ALLOWANCE AS A POND AERATOR

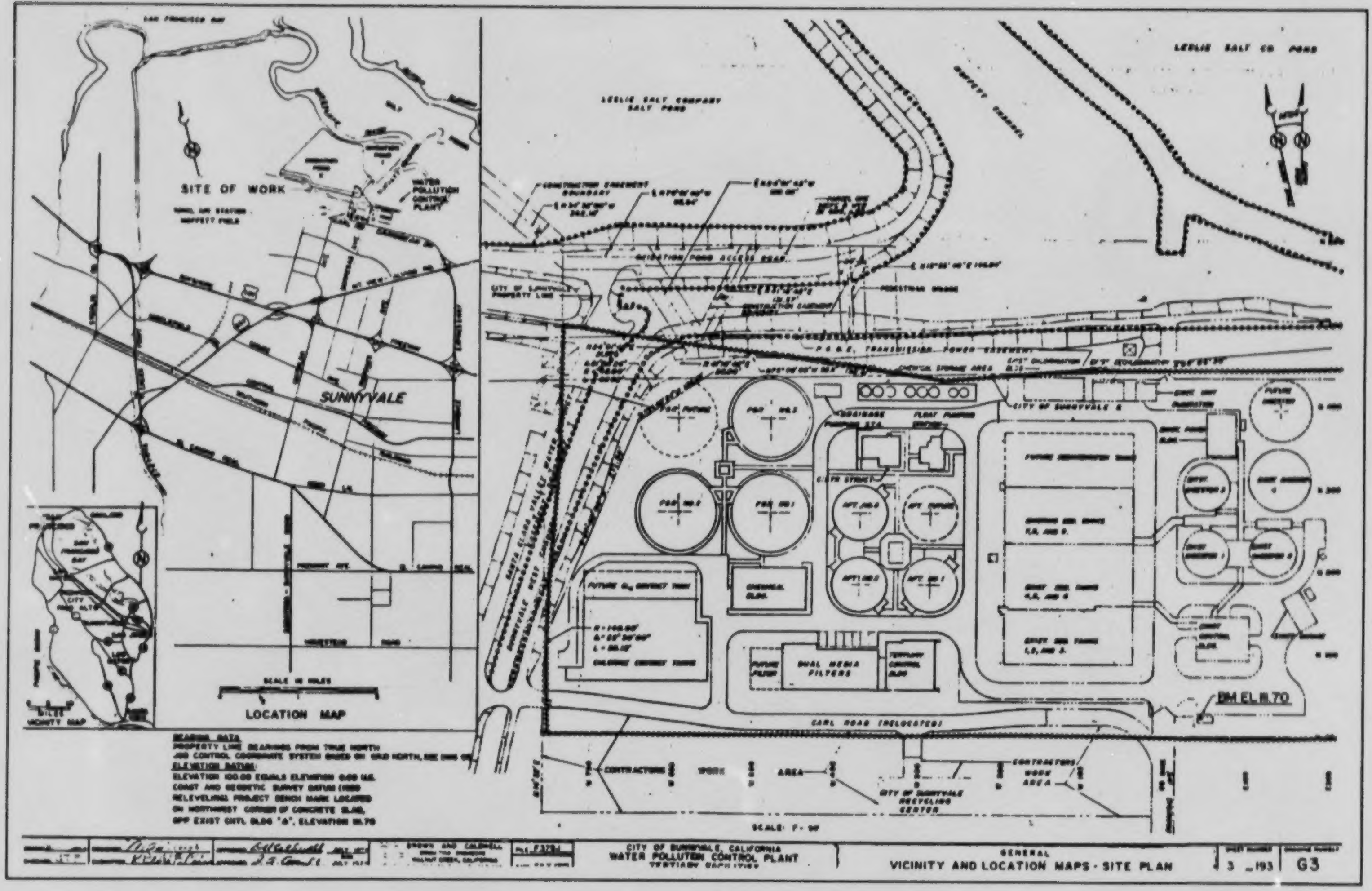
SITE OF WORK
WATER POLLUTION CONTROL PLANT
SUNNYVALE
LOCATION MAP
SCALE IN MILES
VICINITY MAP
LESLIE SALT COMPANY SALT POND
LESLIE SALT CO. POND
P.G.&E. TRANSMISSION POWER EASEMENT
CITY OF SUNNYVALE PROPERTY LINE
PEDESTRIAN BRIDGE
DUAL MEDIA FILTERS
CHEMICAL BLDG.
CHLORINE CONTACT TANKS
BM EL 111.70
CARL ROAD (RELOCATED)
CONTRACTORS WORK AREA
CITY OF SUNNYVALE RECYCLING CENTER
BEARING DATA
PROPERTY LINE BEARINGS FROM TRUE NORTH
ELEVATION DATUM:
ELEVATION 100.00 EQUALS ELEVATION 0.00 U.S. COAST AND GEODETIC SURVEY DATUM
RELEVELING PROJECT BENCH MARK LOCATED ON NORTHWEST CORNER OF CONCRETE SLAB, OPP EXIST CNTL BLDG "A", ELEVATION 111.70
BROWN AND CALDWELL
CITY OF SUNNYVALE, CALIFORNIA
WATER POLLUTION CONTROL PLANT
TERTIARY FACILITIES
GENERAL
VICINITY AND LOCATION MAPS - SITE PLAN
3 _193
G3

FIGURE 5.5 EXPANSION ALLOWANCE FOR INCREASED CAPACITY WITH RESTRICTED AREA

central location of the treatment system is not possible and the use of several operations centers becomes necessary. One arrangement that has been successfully used in small and medium sized plants is to group the primary, aeration and final settling tanks around a central gallery which contains all of the pumps, piping, meters and other support facilities.

The production of odors, mists and plumes must be considered at treatment facilities in residential areas. Unit operations should not be placed where prevailing winds might transport odors to nearby neighborhoods. Additionally, units which produce noise should be muffled and located appropriately on the site. In areas where vandalism occurs, it may be ncessary to eliminate windows on the sides of buildings located on the perimeter of the site.

There are substantial differences in design approach that can result from an appraisal of local climatic conditions. These may include the selection of treatment processes, materials of construction, housing of certain plant components, air conditioning and humidity control, plant drainage, prevention of ice formations, provisions for snow plowing and removal, and protection from high winds. The use of underground galleries and pipe tunnels, although quite common in larger plants, is often ignored in the design of small plants. Such galleries, in facilities of all sizes, are particularly desirable in northern climates. In addition to operator convenience, underground galleries reduce the number of buried pipes and valves.

Discussions with operators in adjacent communities and with local public works officials are helpful in identifying any special provisions needed in the plant layout.

B. Reliability and Flexibility

A wastewater treatment facility should be designed for flexibility and reliability of operation. This includes built-in capabilities for the treatment process to be adapted to changes in regulatory requirements and wastewater loading. It should include design features that facilitate the maintenance and operation of the plant. These features will increase the probability that a properly designed treatment facility will meet its current effluent standards and be able to smoothly adjust to future changes in treatment requirements and loadings to the plant.

C. Selection and Arrangement of Unit Processes

The selection of unit processes should be based on flexibility of operation. Processes should be designed to allow for both maximum and minimum organic, solids and hydraulic loadings. The arrangement of interconnecting piping, and channels for distributing the flow among the treatment units and for transporting it from one component to the next, can have a critical bearing on the operability of a treatment plant. The distribution of flows and solids among treatment units should be designed so that the proper divisions will take place over the entire range of flows to which the plant will be subjected.

Plant hydraulic arrangement should be designed so that the removal of a unit from service does not require that an upstream or downstream unit in the same train be removed. For example, if an aeration tank is taken out of service, it should not be necessary to also remove a settling tank from service at the same time. This means that the effluent channels from multiple tanks should be capable of being joined together and then redivided among the next set of tanks (see Figure 5.6).

The hydraulic capacity of each unit process should be adequate to pass peak plant flow when an individual component of that process is taken out of service. The design should provide for maximum treatment and convenient operation with any given unit out of operation. Special attention should be given to solids retention, sludge handling and disinfection during such periods.

When several components of a unit process are necessary, it behooves the engineer to design in multiples of two wherever possible. This assures maximum use of common facilities such as piping, equipment and structures. The components should be of equal size, thus providing for good hydraulic distribution and maintenance redundancy (see Figure 5.7).

Duplicate design is very important in successful operation of any treatment plant; two bar screens, two grit basins, two primary clarifiers, etc., are recommended. Treatment must continue whenever a piece of equipment has to be taken out of service (see Figure 5.8). If two primary clarifiers are included in a design, then at least three sludge pumps must be available; one for each clarifier in use and one spare. Interconnection of the pump suction and discharge manifolds is recommended so that the discharge from a given pump can be used to backflush the other pump's suction piping.

This type of flexibility can be illustrated by the layout of the Lake Jackson, Texas wastewater treatment plant (Figure 5.9). Normal flow through the facility is indicated by the arrow. However, options are available to enter the aerobic digesters, stabilization tanks, clarifiers or chlorine contact tanks. Bar screens and grit chambers are provided with emergency by-pass channels. Additionally, gates are provided which allow flow between the two digesters, stabilization tanks and/or contact tanks. This design can be operated in extended aeration, activated sludge or contact stabilization modes, and can use either side of the system, both sides or any combination of individual units.

If sufficient land is available, a storage basin capable of holding 2-3 days of flow is another means of increasing plant flexibility and is a desirable design inclusion. Such a basin is especially useful in emergencies when plant flow must be reduced or during periods of storm flows.

D. Equipment and Materials Handling

Ease and efficiency of equipment and materials handling should be a factor in plant design and layout. The designer must identify the quantity, size of shipment, and frequency of chemicals being delivered to the site. Wherever possible, the need to rehandle chemicals within the plant should be

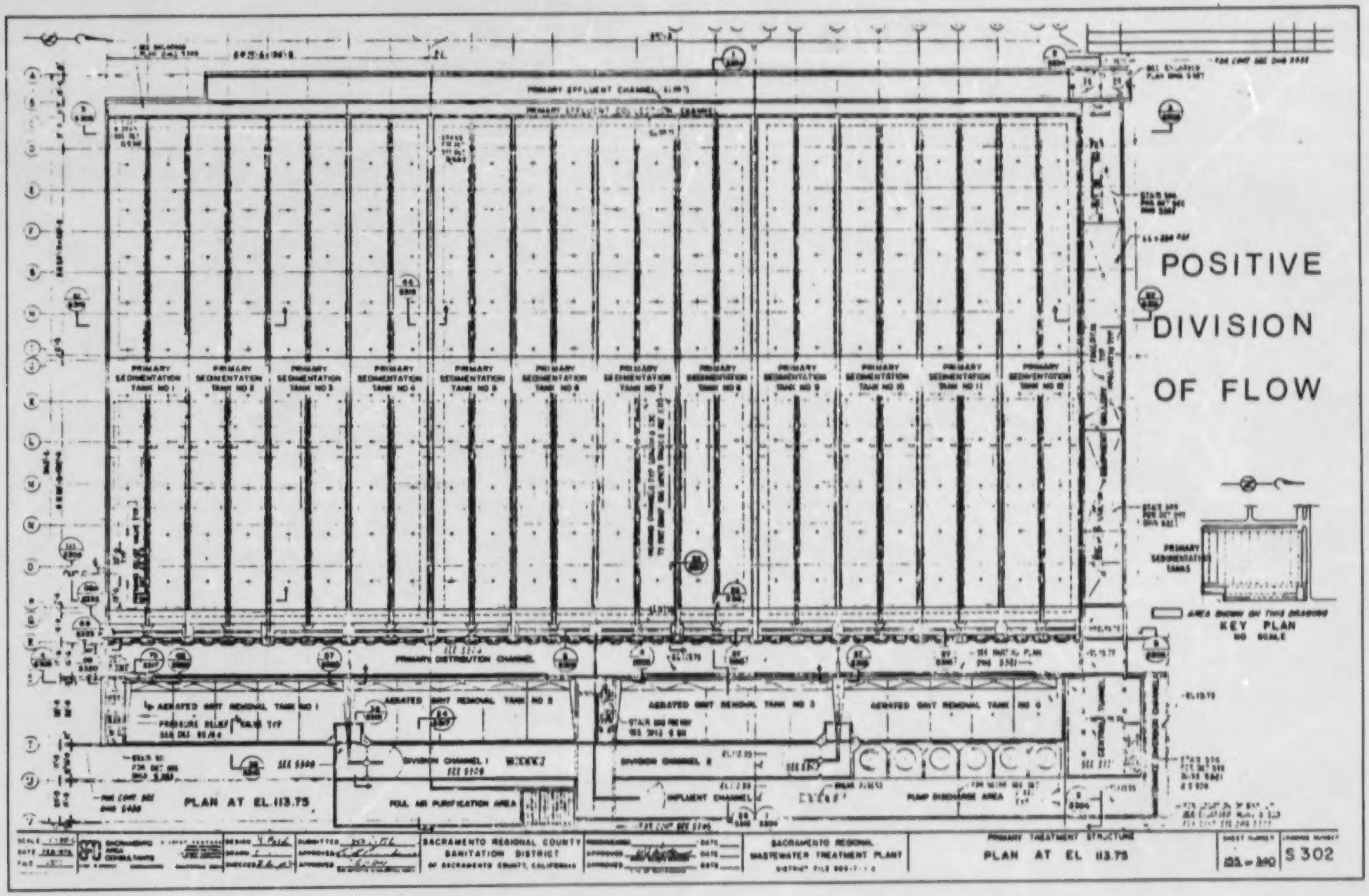
POSITIVE
DIVISION
OF FLOW
PRIMARY EFFLUENT CHANNEL
PRIMARY EFFLUENT COLLECTION CHANNEL
PRIMARY SEDIMENTATION TANK NO 1
PRIMARY SEDIMENTATION TANK NO 2
PRIMARY SEDIMENTATION TANK NO 3
PRIMARY SEDIMENTATION TANK NO 4
PRIMARY SEDIMENTATION TANK NO 5
PRIMARY SEDIMENTATION TANK NO 6
PRIMARY SEDIMENTATION TANK NO 7
PRIMARY SEDIMENTATION TANK NO 8
PRIMARY SEDIMENTATION TANK NO 9
PRIMARY SEDIMENTATION TANK NO 10
PRIMARY SEDIMENTATION TANK NO 11
PRIMARY SEDIMENTATION TANK NO 12
PRIMARY DISTRIBUTION CHANNEL
AERATED GRIT REMOVAL TANK NO 1
AERATED GRIT REMOVAL TANK NO 2
AERATED GRIT REMOVAL TANK NO 3
AERATED GRIT REMOVAL TANK NO 4
PRESSURE RELIEF TANK TYP
DIVISION CHANNEL 1
DIVISION CHANNEL 2
INFLUENT CHANNEL
FOUL AIR PURIFICATION AREA
PUMP DISCHARGE AREA
PLAN AT EL.113.75
PRIMARY SEDIMENTATION TANKS
AREA SHOWN ON THIS DRAWING
KEY PLAN
NO SCALE
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
PRIMARY TREATMENT STRUCTURE
PLAN AT EL 113.75
S 302

FIGURE 5.6 FLEXIBILITY FOR POSITIVE DIVISION OF FLOW

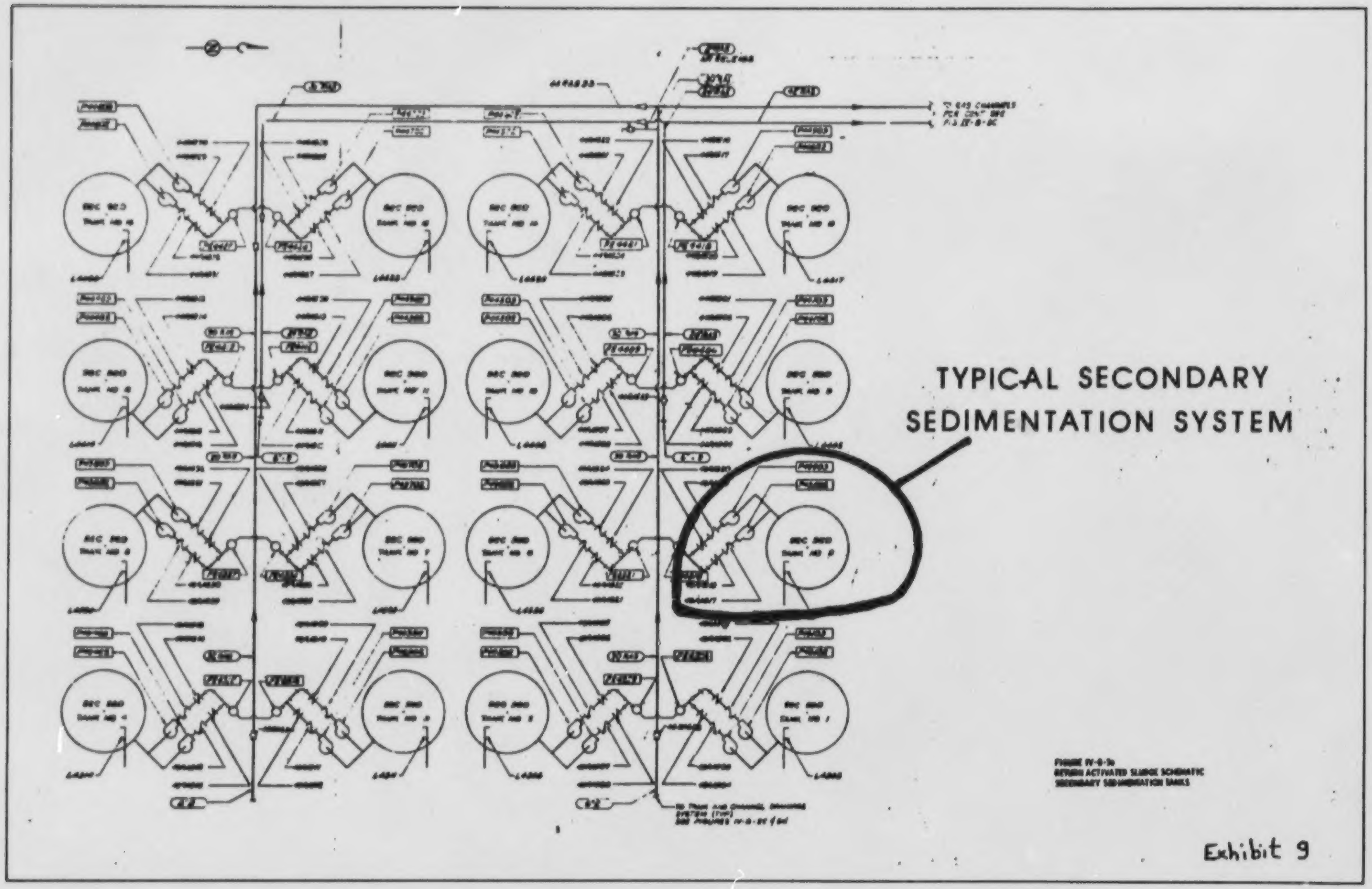
TYPICAL SECONDARY SEDIMENTATION SYSTEM
FIGURE IV-B-2b
RETURN ACTIVATED SLUDGE SCHEMATIC
SECONDARY SEDIMENTATION TANKS

Exhibit 9

FIGURE 5.7 DUPLICATION FOR GOOD HYDRAULIC DISTRIBUTION AND MAINTENANCE REDUNDANCY

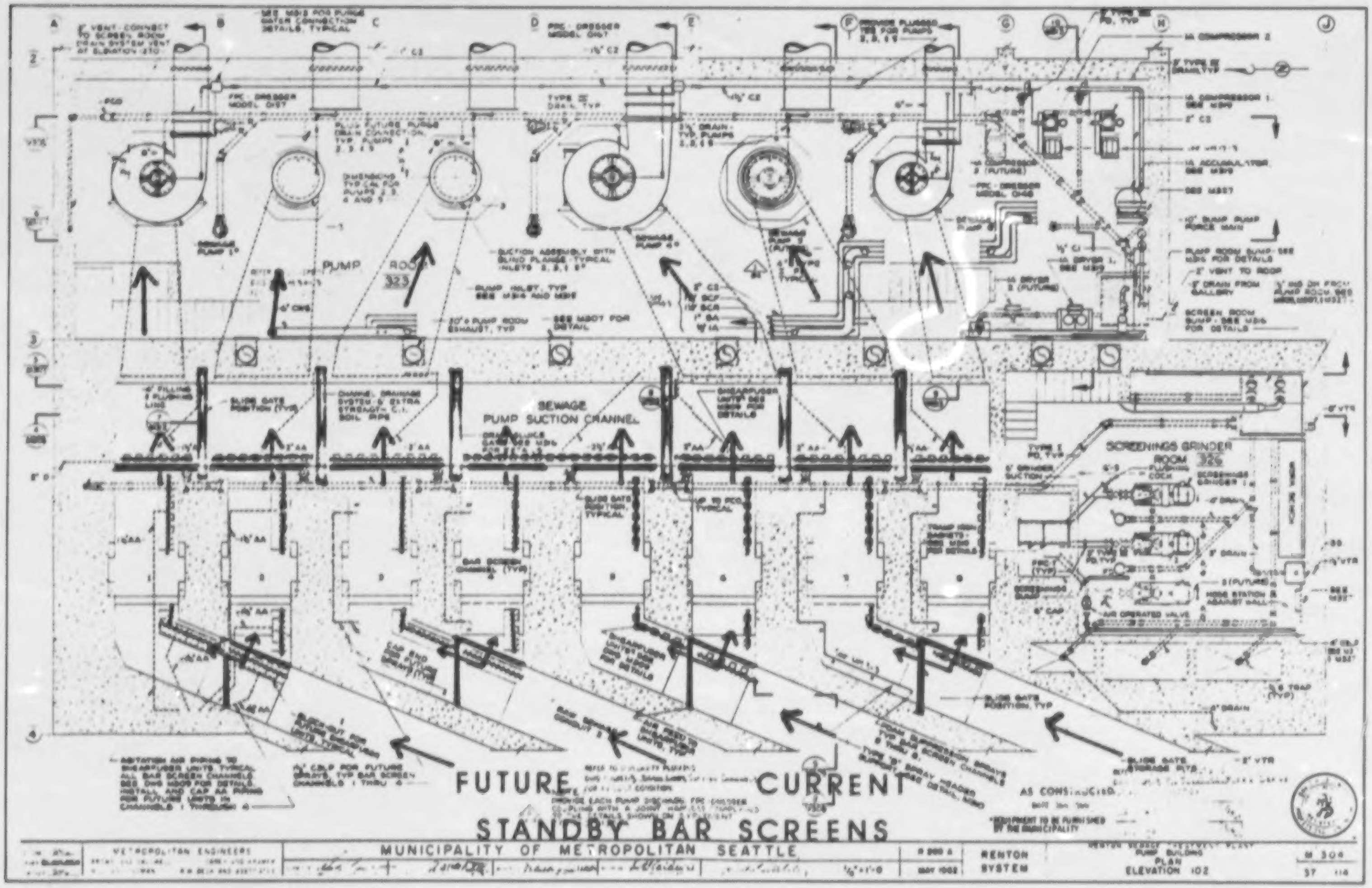
PUMP ROOM 323
SEWAGE PUMP SUCTION CHANNEL
SCREENINGS GRINDER ROOM 326
FUTURE
CURRENT
STANDBY BAR SCREENS
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
RENTON SYSTEM
PLAN
ELEVATION 102
M 304

FIGURE 5.8 DUPLICATION AND DISTRIBUTION FLEXIBILITY IN SUCCESSIVE TREATMENT UNITS

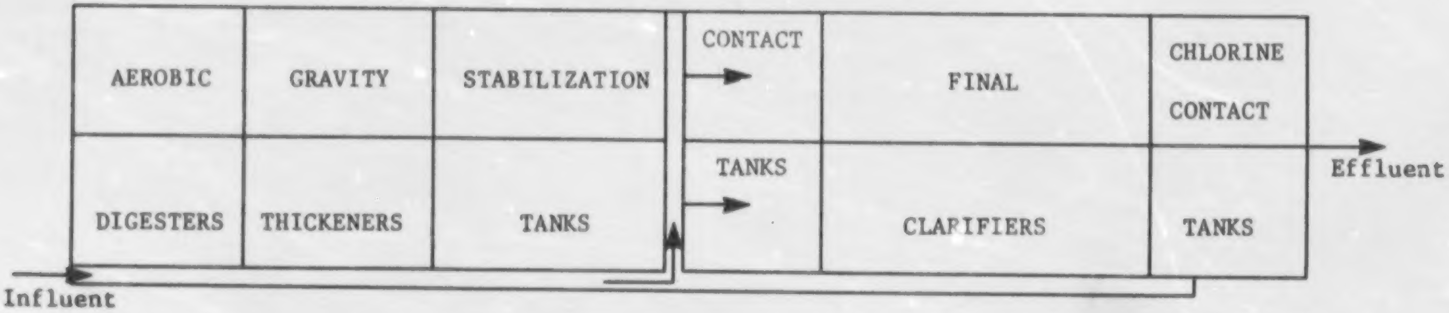
AEROBIC
DIGESTERS
GRAVITY
THICKENERS
STABILIZATION
TANKS
CONTACT
TANKS
FINAL
CLARIFIERS
CHLORINE
CONTACT
TANKS
Effluent
Influent

FIGURE 5.9 LAKE JACKSON, TEXAS, WASTEWATER TREATMENT PLANT LAYOUT

avoided. For example, bagged lime and dry polymer used for sludge dewatering should be stored on the same floor as the solution tanks and as close to them as possible. Residue handling must also be considered. If screenings are to be hauled off-site, then trucks must have easy access to the screen room.

Cranes, hoists and lifting inserts should be provided throughout a plant wherever heavy equipment or materials have to be raised off the floor (see Figures 5.10, 5.11 and 5.12). There should be ready access to all equipment so that when failure occurs or maintenance is necessary, repairs can be done quickly. Proper access design should include wide galleries for the passage of forklifts and other machinery.

Alignment support should be located above large pumps so that when pump mechanisms are removed for maintenance they are lifted straight out of the pump housing. Electrical connections for these pumps must be designed for easy uncoupling before maintenance begins. When it is necessary to disassemble large pieces of equipment, a floor support for the piece should be provided. Additionally, the underlying gallery floor should be structurally reinforced.

E. Maintenance Considerations

Easy access to all equipment valves, gates and other operating devices should be provided. Drain gates for aeration basins, and all structures that must be drained, should be recessed up to the crown of the pipe so that tanks can be drained completely (see Figure 5.13). The drainage system should be designed so that a structure can be completely emptied within six hours. This will insure that a tank can be drained and cleaned within one shift.

Maintenance and operation of the plant can be further enhanced by locating utility stations thoughout all tunnels and equipment areas (see Figures 5.14 and 5.15). Wash-down water, service air, steam or potable water should be provided within reach of 50-foot hoses. Electrical outlets should be readily available throughout a treatment plant. Excessive use of electrical extension cords or temporary wiring should be avoided.

All galleries and utility tunnels should be drained, painted, illuminated and ventilated to obtain a good working environment. A color coding system will aid the plant maintenance staff in carrying out lubrication schedules. A color coded tag or decal should be affixed to each piece of equipment near the lubrication point. The labels should identify the parts to be lubricated and the required types, frequencies and amount of lubricants. A recommended system for grease and oils is to use a different color for each frequency of lubrication. A recommended color code is:

Brown	Annually
Red	Semi-Annually
Blue	Monthly
Green	Weekly
White	Daily

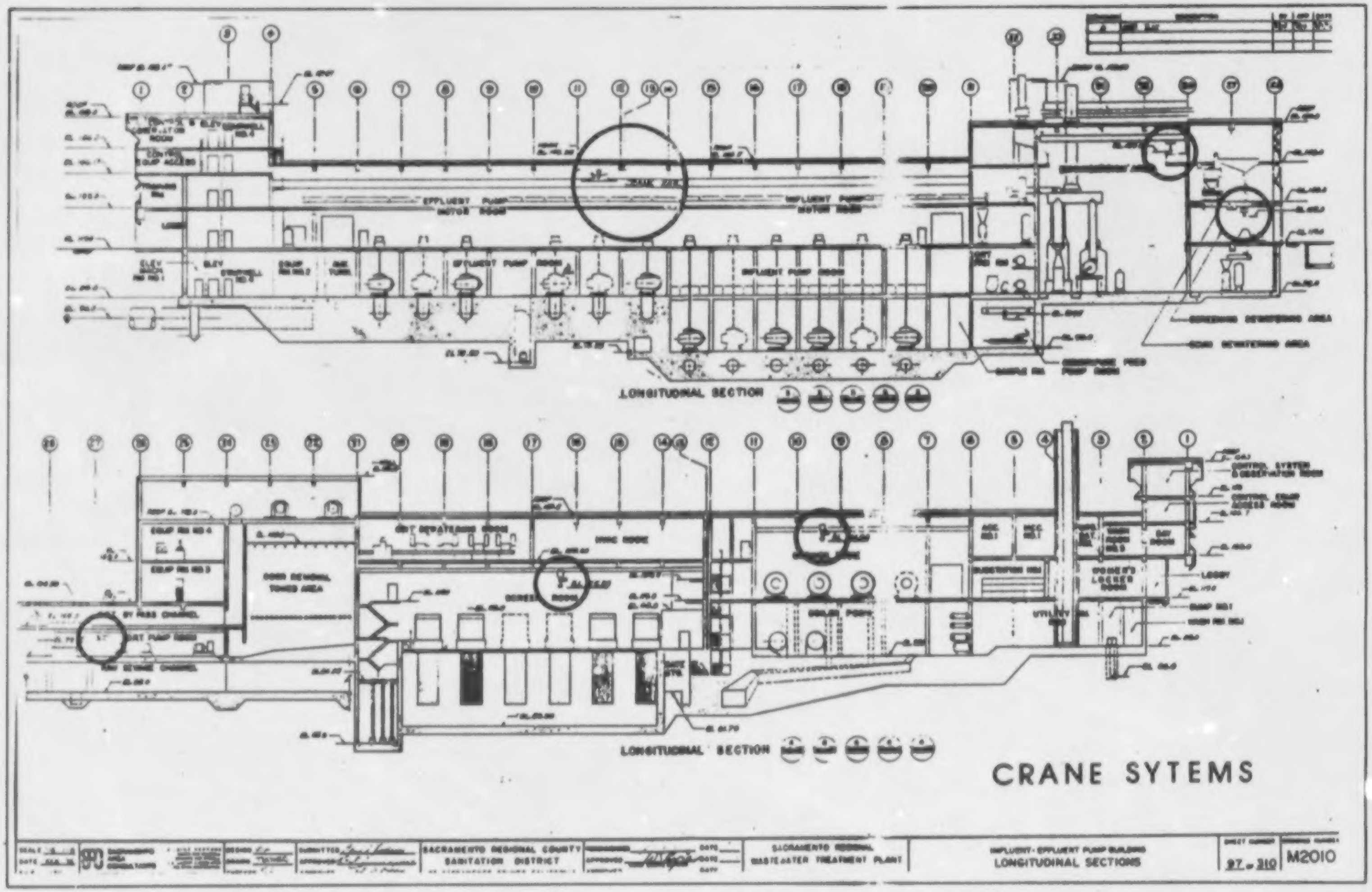
EFFLUENT PUMP MOTOR ROOM
INFLUENT PUMP MOTOR ROOM
EFFLUENT PUMP ROOM
INFLUENT PUMP ROOM
SCREENINGS DEWATERING AREA
GRIT DEWATERING AREA
LONGITUDINAL SECTION
GRIT DEWATERING ROOM
HVAC ROOM
ODOR REMOVAL TOWER AREA
BOILER ROOM
WOMEN'S LOCKER ROOM
LOBBY
LONGITUDINAL SECTION
CRANE SYTEMS
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
INFLUENT-EFFLUENT PUMP BUILDING
LONGITUDINAL SECTIONS
97 of 310
M2010

FIGURE 5.10 ADEQUATE PROVISION OF CRANE SYSTEM

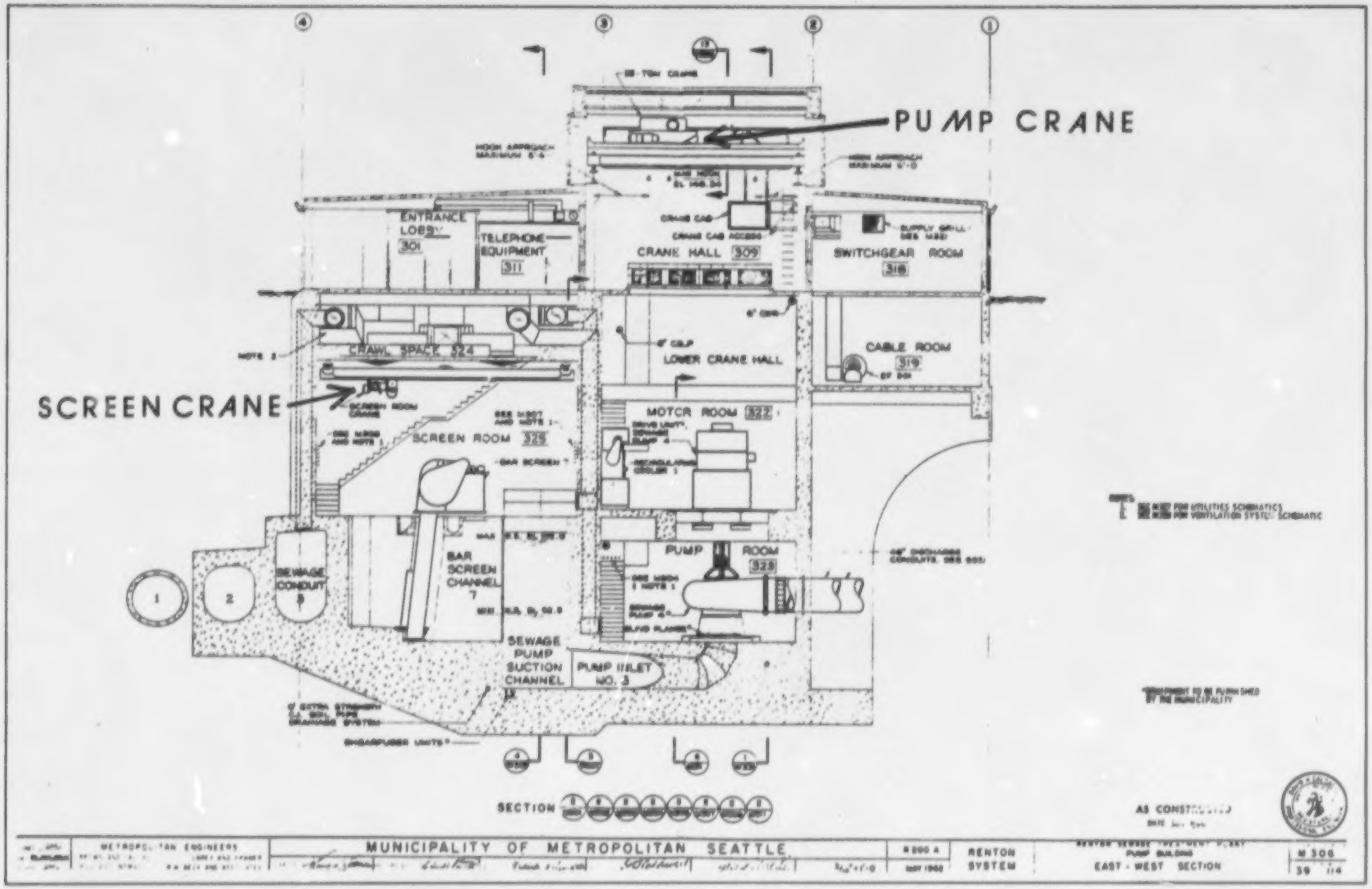
PUMP CRANE
SCREEN CRANE
ENTRANCE LOBBY 301
TELEPHONE EQUIPMENT 311
CRANE HALL 309
SWITCHGEAR ROOM 318
CRAWL SPACE 324
LOWER CRANE HALL
CABLE ROOM 319
MOTOR ROOM 322
SCREEN ROOM 325
PUMP ROOM 323
BAR SCREEN CHANNEL 7
SEWAGE CONDUIT 3
1
2
SEWAGE PUMP SUCTION CHANNEL 12
PUMP INLET NO. 3
CRANE CAB
SECTION
AS CONSTRUCTED
MUNICIPALITY OF METROPOLITAN SEATTLE
METROPOLITAN ENGINEERS
RENTON SYSTEM
PUMP BUILDING
EAST - WEST SECTION
M 306

FIGURE 5.11 GOOD POSITIONING OF CRANES

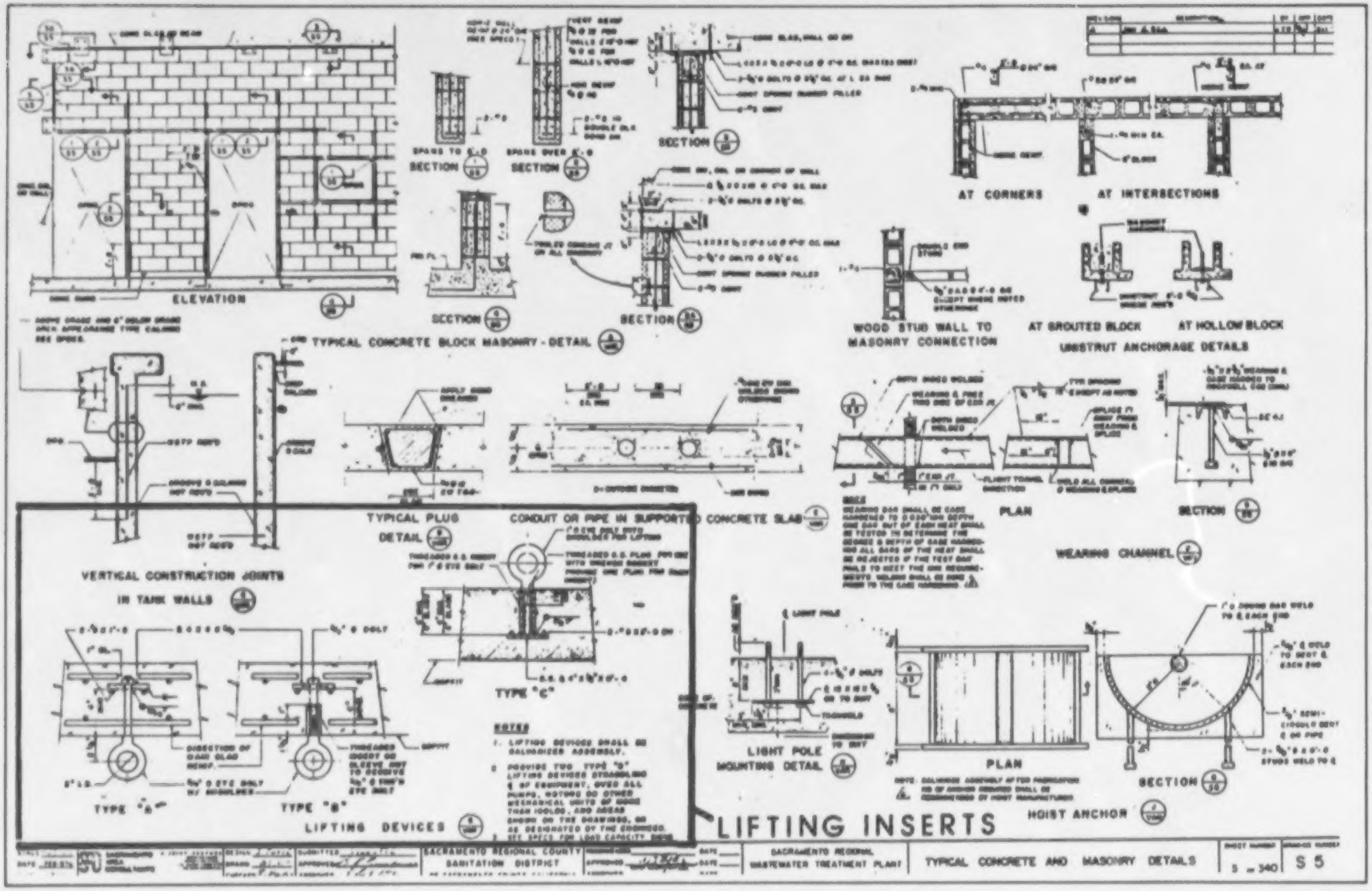
ELEVATION
SECTION
TYPICAL CONCRETE BLOCK MASONRY - DETAIL
AT CORNERS
AT INTERSECTIONS
WOOD STUD WALL TO MASONRY CONNECTION
AT GROUTED BLOCK
AT HOLLOW BLOCK
UNISTRUT ANCHORAGE DETAILS
VERTICAL CONSTRUCTION JOINTS IN TANK WALLS
TYPICAL PLUG DETAIL
CONDUIT OR PIPE IN SUPPORTED CONCRETE SLAB
PLAN
WEARING CHANNEL
TYPE "C"
TYPE "A"
TYPE "B"
LIFTING DEVICES
NOTES
LIFTING INSERTS
LIGHT POLE MOUNTING DETAIL
HOIST ANCHOR
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
TYPICAL CONCRETE AND MASONRY DETAILS
S-340
S 5

FIGURE 5.12 DESIGN DETAIL FOR LIFTING INSERTS

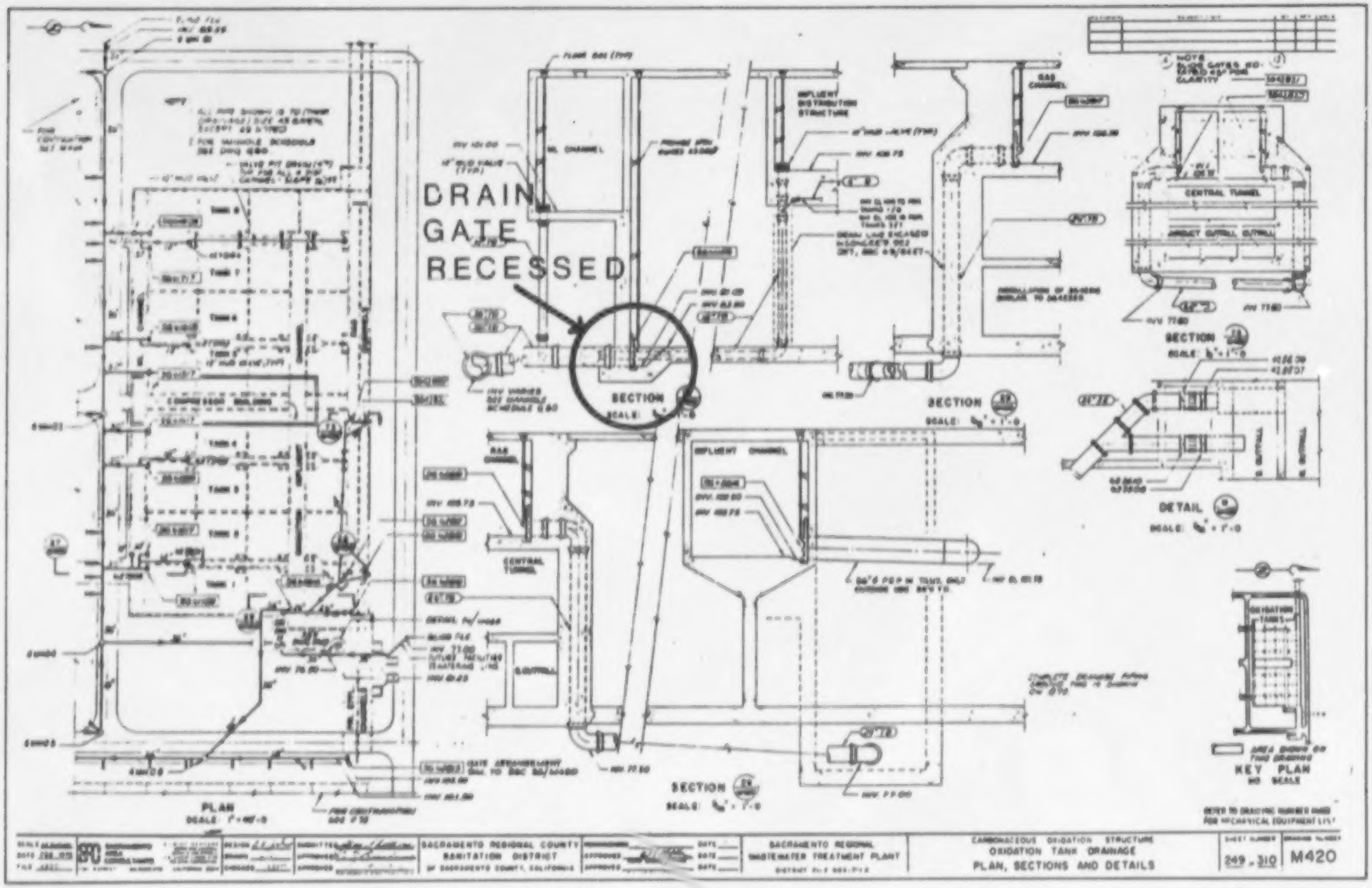
DRAIN GATE RECESSED
SECTION
PLAN
SECTION
DETAIL
KEY PLAN
NO SCALE
CENTRAL TUNNEL
INFLUENT CHANNEL
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
CARBONACEOUS OXIDATION STRUCTURE
OXIDATION TANK DRAINAGE
PLAN, SECTIONS AND DETAILS
249 - 310
M420

FIGURE 5.13 RECESSED DRAIN GATE FOR COMPLETE DRAINAGE

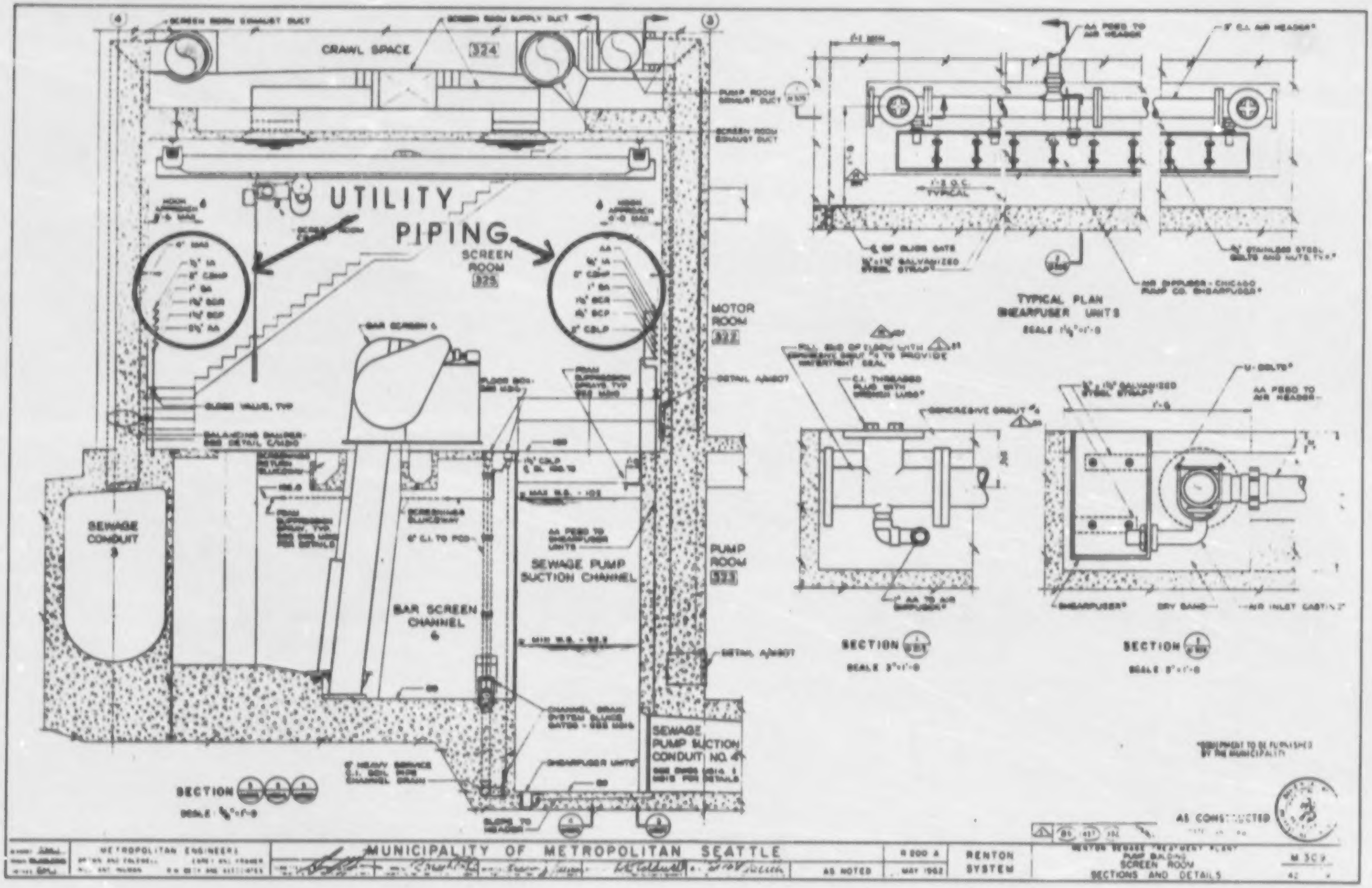
CRAWL SPACE
324
UTILITY
PIPING
SCREEN ROOM
325
MOTOR ROOM
322
PUMP ROOM
323
SEWAGE CONDUIT
BAR SCREEN CHANNEL
SEWAGE PUMP SUCTION CHANNEL
SEWAGE PUMP SUCTION CONDUIT NO. 4
SECTION
TYPICAL PLAN SHEARFUSER UNITS
AS CONSTRUCTED
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
AS NOTED
MAY 1962
RENTON SYSTEM
SCREEN ROOM
SECTIONS AND DETAILS

FIGURE 5.14 UTILITY PIPING WITH CLEAR ACCESS FOR MAINTENANCE AND USE

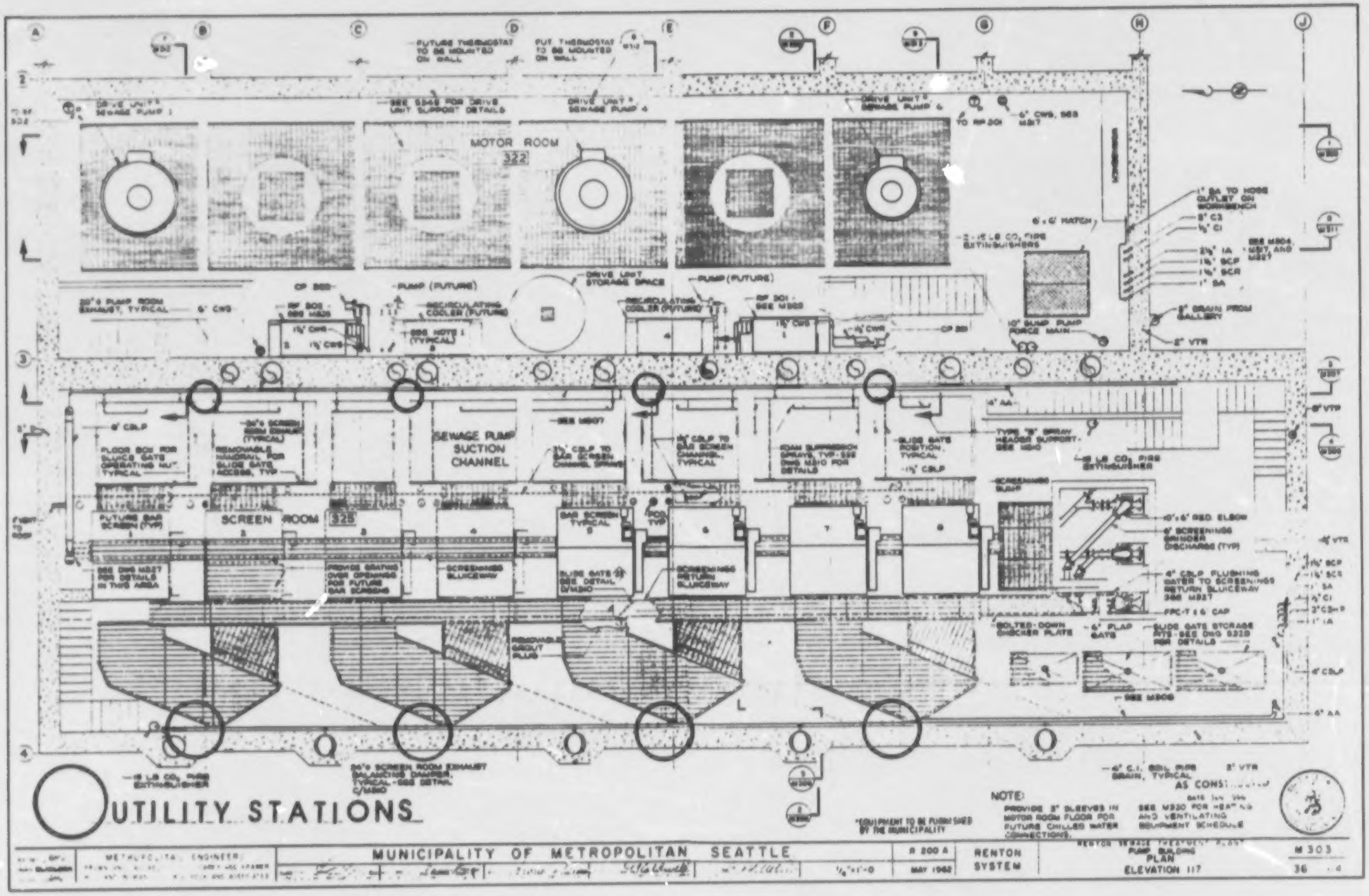
MOTOR ROOM
322
SEWAGE PUMP SUCTION CHANNEL
SCREEN ROOM
325
UTILITY STATIONS
NOTE:
AS CONSTRUCTED
MUNICIPALITY OF METROPOLITAN SEATTLE
METROPOLITAN ENGINEERS
RENTON SYSTEM
MAY 1962
PLAN
ELEVATION 117
M 303

FIGURE 5.15 GOOD DISTRIBUTION OF UTILITY STATIONS

F. Automation

Computer control is becoming more common in plants of all sizes. However, there should be field capabilities for manual control at each point along the treatment train. There should also be local control centers which are hardwired into all processes (see Figure 5.16). This means that the plant can be manually controlled if the computer goes down. The operability of computer systems is highly dependent on the sensing equipment used. Even the most sophisticated digital process control systems will be worthless without reliable sensing elements which receive regular maintenance.

The degree of automation and instrumention to be incorporated into a plant must be selected based on a practical understanding of plant operation. Experience has indicated that many start-up and operating problems are associated with instrumentation. Visits to plants after several years of operation have revealed that a significant portion of sophisticated instrumentation is not being used. Automation should be kept to a minimum in small plants. The major criteria for the use of automation should be that it will either insure more reliable and consistent effluent quality or significantly reduce manpower, chemical, energy or other costs. In small plants, it can be very difficult to train an operator to service sophisticated control systems and components. However, the judicious use of timers is very practical even in the smallest of plants. Normally, it is desirable to equip any automatic control system with a manual mode by the use of "hands. off" automatic selector switches.

G. Installation

Special attention should be given during equipment installation to the inspection of the contractor's work. Alignment of pumps, motors and fans; proper pump and valve packing; and instrumentation control and alarm systems should be carefully checked.

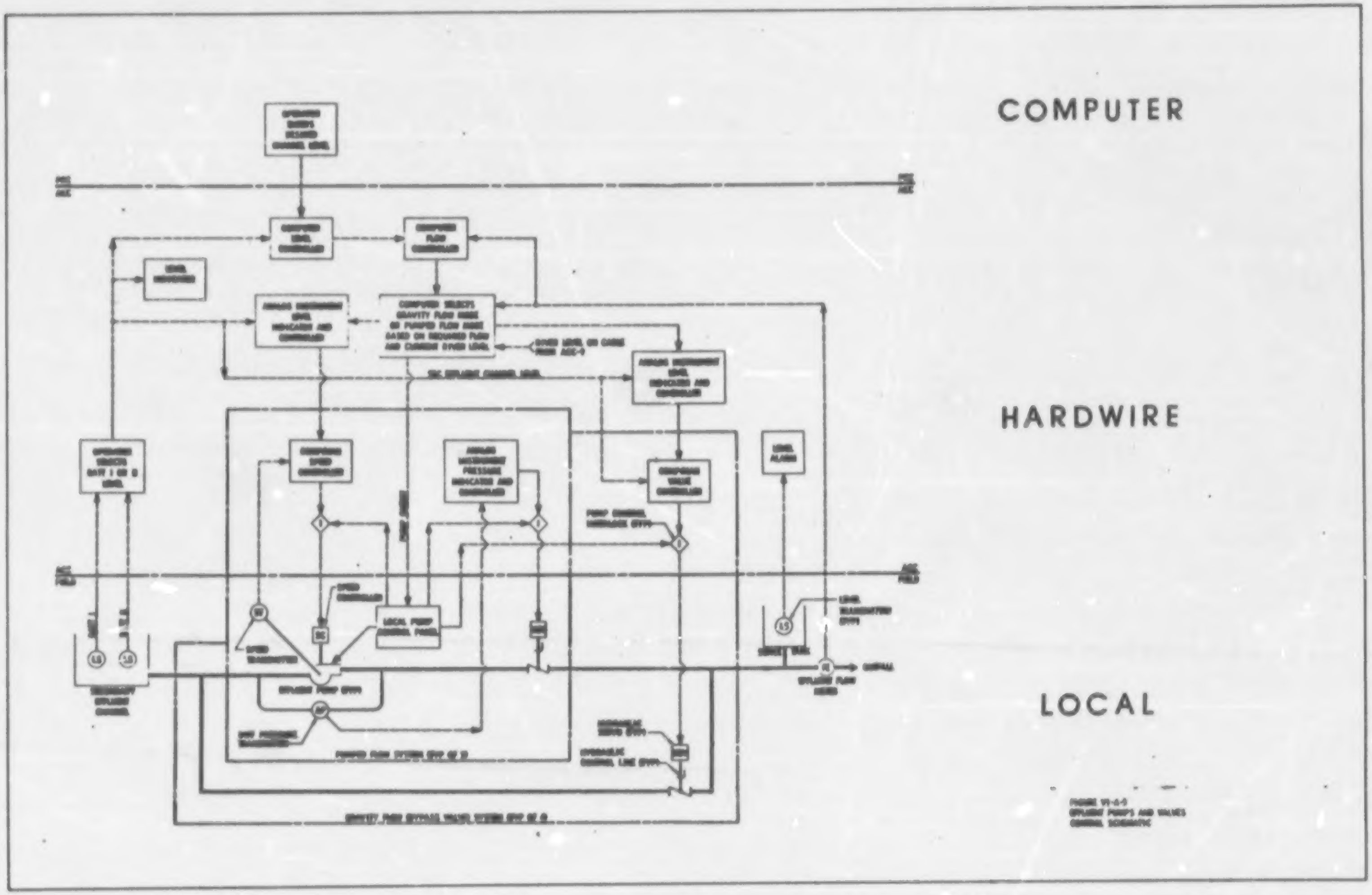
COMPUTER
HARDWIRE
LOCAL

FIGURE 5.16 LOCAL CONTROL OF COMPUTER SYSTEM VIA HANDWIRING

UNIT PROCESS DESIGN - PRELIMINARY TREATMENT

UNIT 6

UNIT 6 - UNIT PROCESS DESIGN - PRELIMINARY TREATMENT

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- Define preliminary treatment.
- Identify factors which affect preliminary treatment facilities selection.
- Discuss at least four elements which should be included in the design of influent channels.
- Describe four types of screening devices, their utilization and important design considerations.
- List at least five important facts to be taken into consideration when designing screenings handling facilities.
- Explain four desirable attributes of comminutors which the designer can utilize.
- Explain the theoretical considerations underlying grit collector design.
- Identify Stokes' Law and describe its importance.
- Design a grit tank based on hypothetical needs.
- Discuss at least five important preliminary treatment "design hints" which have been presented.
- Write a description of grit dewatering.
- Design an efficient raw wastewater pump system that is relatively easy to operate and maintain.

UNIT 6 - UNIT PROCESS DESIGN - PRELIMINARY TREATMENT

A. General Considerations

Preliminary treatment generally consists of two processes: screening and grit removal. Screens or racks intercept coarse sewage solids, while grit removal collects the heavy materials that have subsidence velocities substantially greater than the organic putresible solids in wastewater. Bar screens are usually located ahead of the influent pumps (see Figure 6.1). Grit tanks are usually located between these pumps and the primary settling tanks (see Figure 6.2).

Since preliminary treatment is situated at the head of a plant, this process is subject to unattenuated fluctuations in diurnal and storm flows of raw wastewater as it leaves the city sewer system. For this reason, structural isolation of all portions of the preliminary treatment system should be provided for, including all equipment and drains (see Figures 6.3 and 6.4). This procedure will protect the rest of the plant should flooding of the headworks occur. As additional protection from flooding, there should be no cross connections or electrical switchgear below the maximum water level, should all pumps fail. For emergency operation and maintenance, the capacity to isolate the headworks from the raw influent should be a part of plant design.

Proper ventilation of the screen room is imperative, as raw wastewater is often septic when it enters the treatment plant. If continuous ventilation is not provided, hydrogen sulfide may accumulate and create both odors and a health hazard. Ventilation air from clean areas can be used twice by recycling it through the screen room (see Figure 6.5). Exhaust pipes should be placed just above the sewage conduits and above the sewage pump suction level (see Figure 6.6). These should be connected to biological and activated carbon scrubbers to reduce odor levels. For aesthetic purposes, the exhaust pipes may be placed in screen room walls. As further safety features, exhaust ventilation should be continuously monitored and separate entrances and exits to the screen room should be provided.

Because of the nature of the treatment process, the screen room must be adequately designed for maintenance. Cranes and lifting inserts should be provided to remove and install bar screens, grinders, slide gates, etc. Truck access should be convenient for handling equipment and excess debris (see Figure 6.7). Utility stations with air, water, steam connections and service sinks should be located in convenient areas. By mounting equipment on concrete pads, it will be easier to clean these areas after flooding.

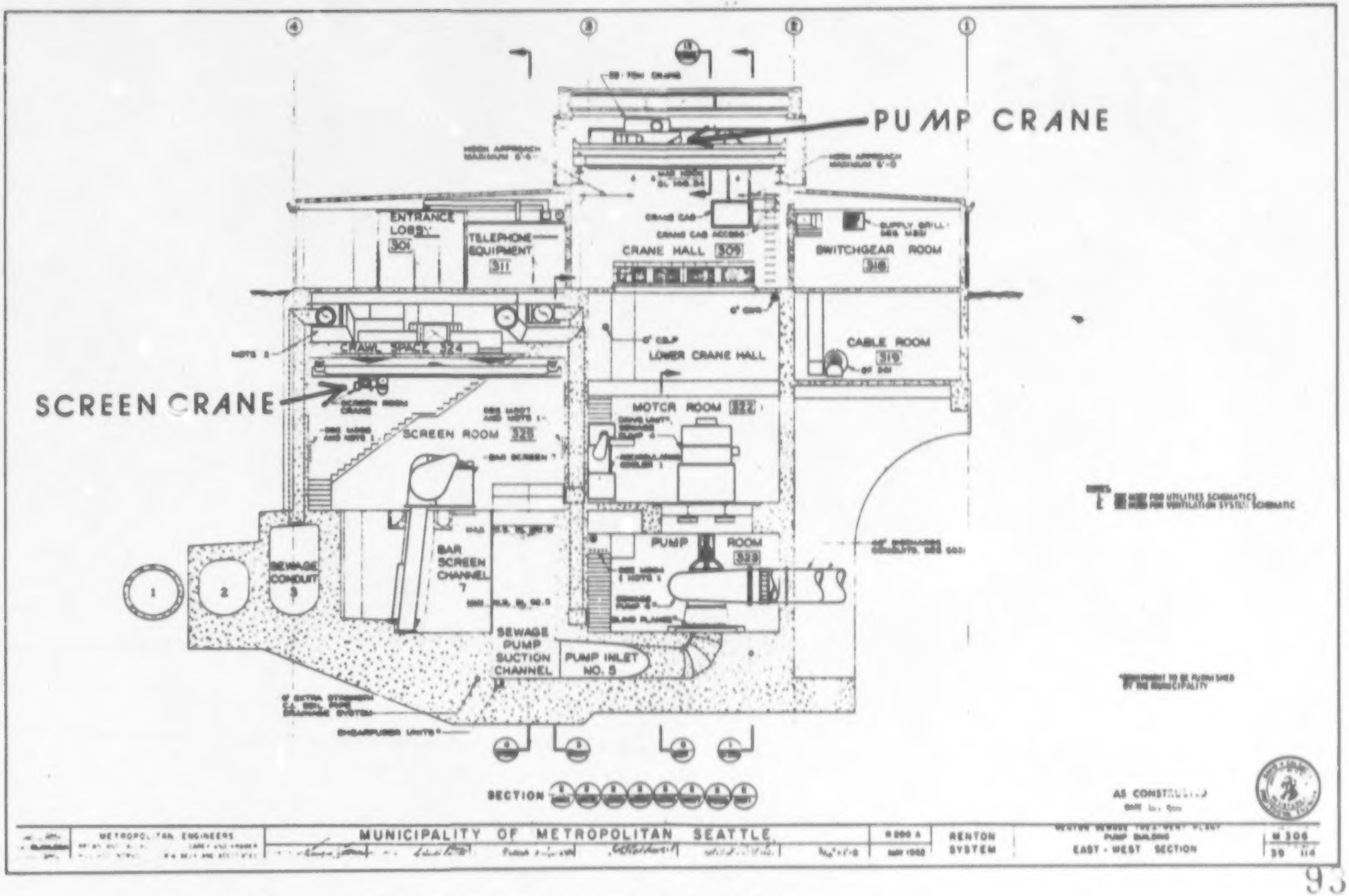
PUMP CRANE
SCREEN CRANE
ENTRANCE LOBBY 301
TELEPHONE EQUIPMENT 311
CRANE CAB
CRANE HALL 309
SWITCHGEAR ROOM 318
CRAWL SPACE 324
LOWER CRANE HALL
CABLE ROOM 319
SCREEN ROOM CRANE
SCREEN ROOM 325
BAR SCREEN 7
MOTOR ROOM 322
PUMP ROOM 323
SEWAGE CONDUIT 3
1
2
BAR SCREEN CHANNEL 7
SEWAGE PUMP SUCTION CHANNEL
PUMP INLET NO. 5
SECTION
AS CONSTRUCTED
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
RENTON SYSTEM
PUMP BUILDING
EAST - WEST SECTION
M 306
39 114

FIGURE 6.1 DESIRABLE LOCATION OF BAR SCREENS

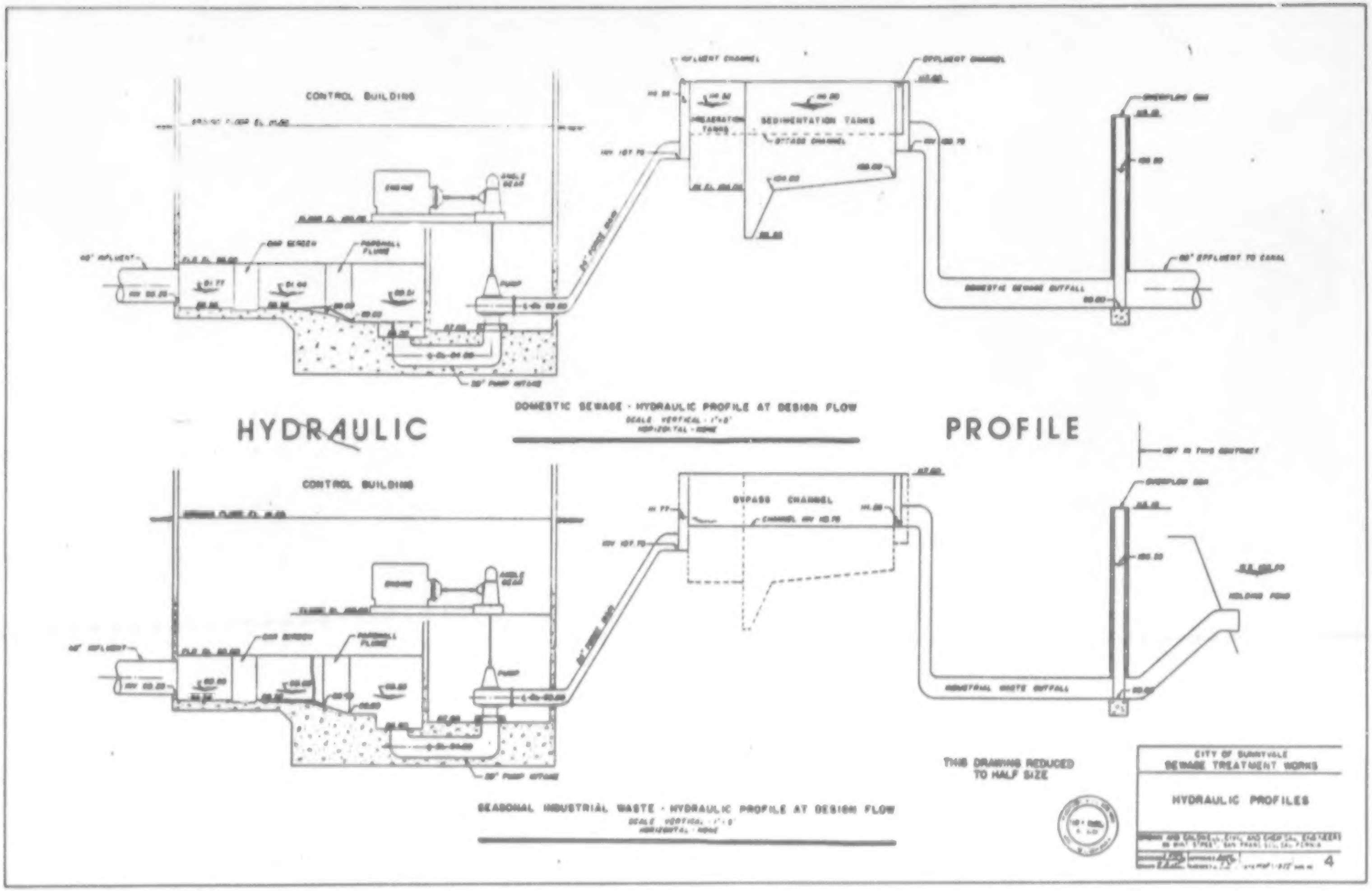
CONTROL BUILDING
ENGINE
ANGLE GEAR
BAR SCREEN
PARSHALL FLUME
PUMP
20" PUMP INTAKE
INFLUENT CHANNEL
EFFLUENT CHANNEL
PREAERATION TANKS
SEDIMENTATION TANKS
BYPASS CHANNEL
OVERFLOW DAM
60" EFFLUENT TO CANAL
DOMESTIC SEWAGE OUTFALL
DOMESTIC SEWAGE - HYDRAULIC PROFILE AT DESIGN FLOW
HYDRAULIC
PROFILE
NOT IN THIS CONTRACT
BYPASS CHANNEL
HOLDING POND
INDUSTRIAL WASTE OUTFALL
SEASONAL INDUSTRIAL WASTE - HYDRAULIC PROFILE AT DESIGN FLOW
THIS DRAWING REDUCED TO HALF SIZE
CITY OF SUNNYVALE
SEWAGE TREATMENT WORKS
HYDRAULIC PROFILES
4

FIGURE 6.2 LOCATION OF GRIT COLLECTORS WITH GOOD HYDRAULIC PROFILE

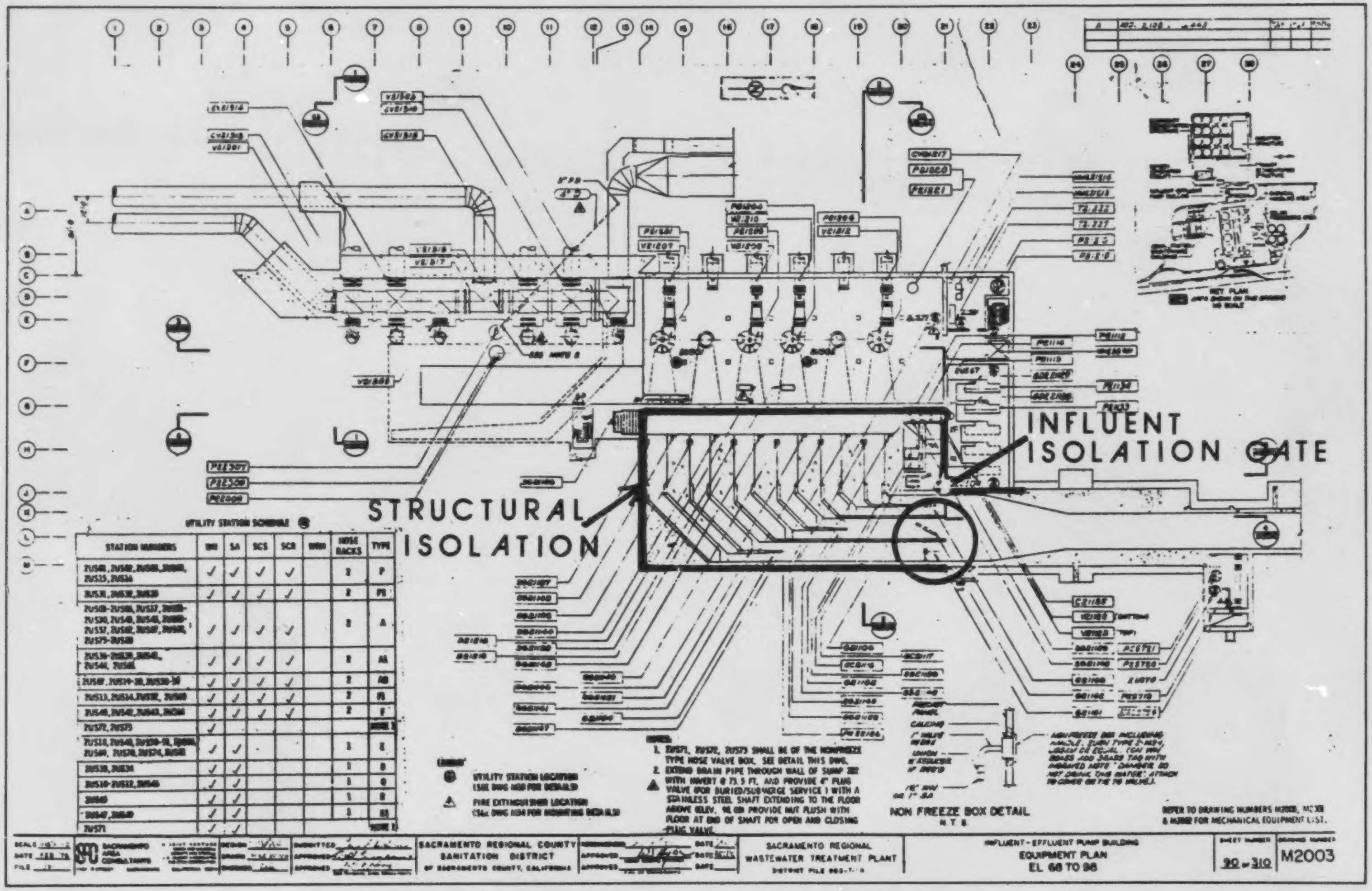
INFLUENT ISOLATION GATE
STRUCTURAL ISOLATION
UTILITY STATION SCHEDULE
NON FREEZE BOX DETAIL
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
INFLUENT-EFFLUENT PUMP BUILDING
EQUIPMENT PLAN
EL 68 TO 98
90 of 310
M2003

FIGURE 6.3 STRUCTURAL ISOLATION OF INFLOW

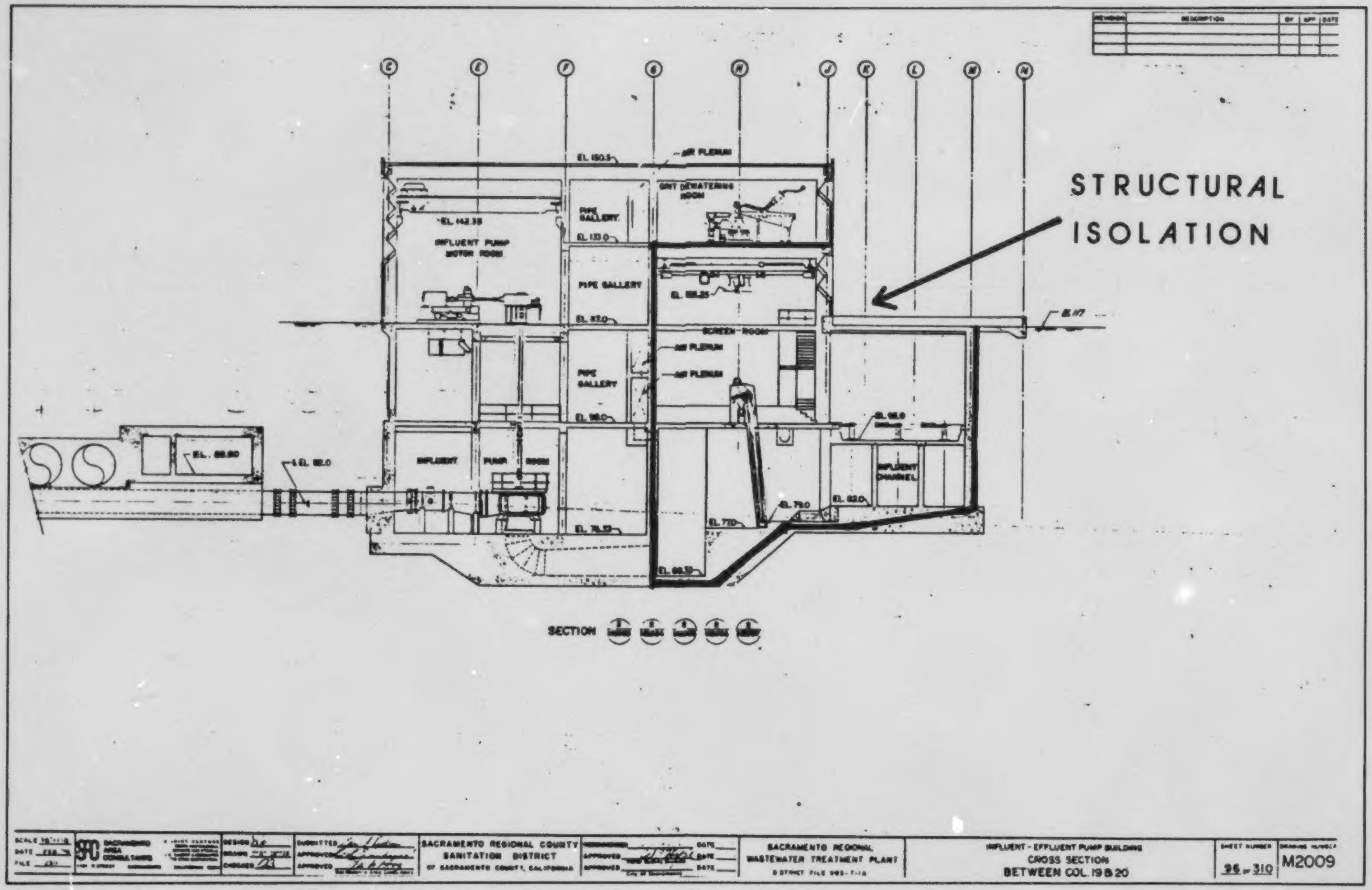
STRUCTURAL ISOLATION
EL 150.5
AIR PLENUM
GRIT DEWATERING ROOM
PIPE GALLERY
EL 142.38
INFLUENT PUMP MOTOR ROOM
EL 133.0
PIPE GALLERY
EL 108.25
EL 117.0
EL 117
SCREEN ROOM
AIR PLENUM
AIR PLENUM
PIPE GALLERY
EL 98.0
EL 96.0
EL. 86.90
EL 82.0
INFLUENT PUMP ROOM
INFLUENT CHANNEL
EL 79.0
EL 77.0
EL 82.0
EL 76.33
EL 66.33
SECTION
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
INFLUENT - EFFLUENT PUMP BUILDING
CROSS SECTION
BETWEEN COL. 19 & 20
96 of 310
M2009

FIGURE 6.4 STRUCTURAL ISOLATION OF INFLOW

100

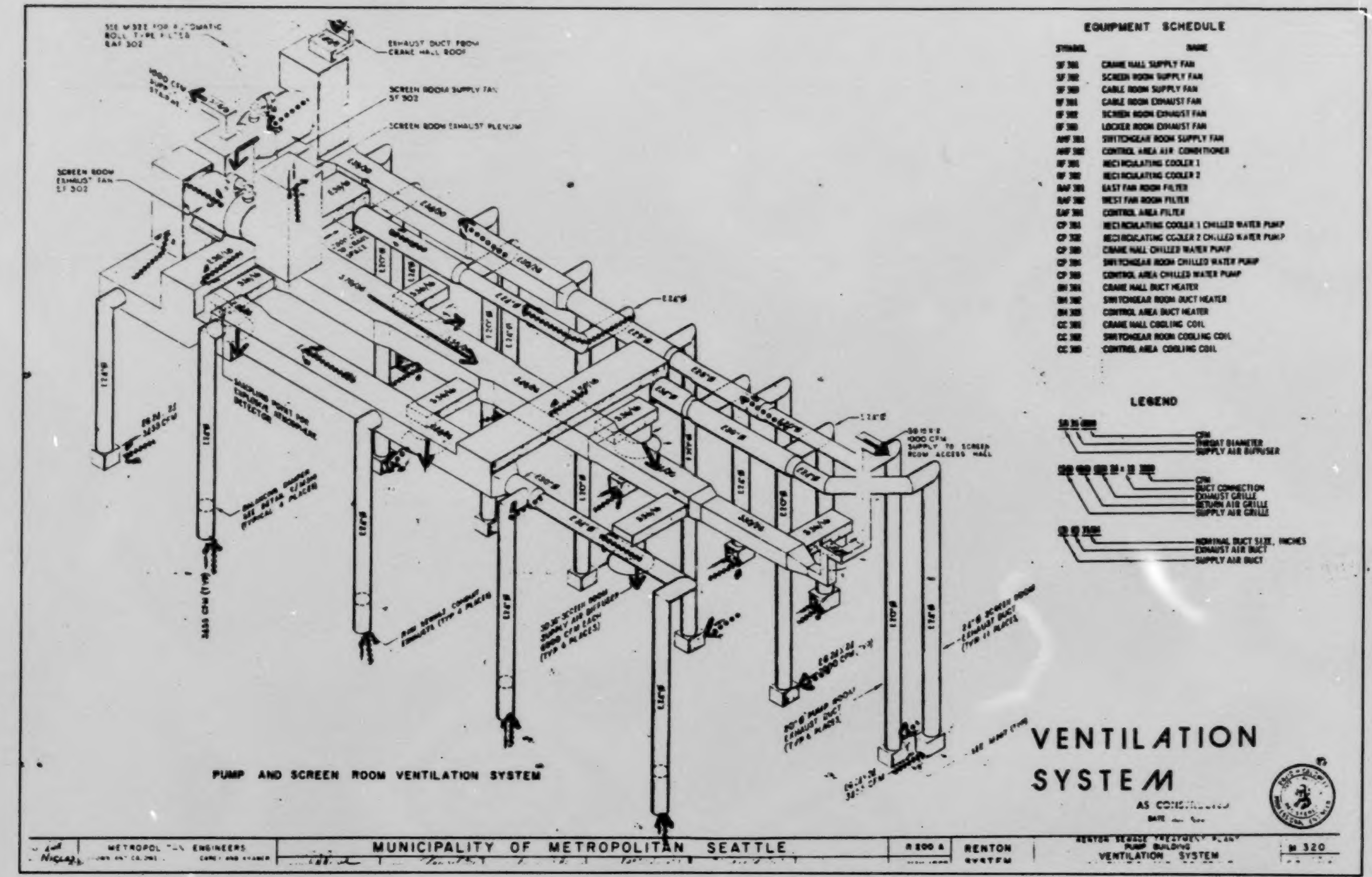
EXHAUST DUCT FROM CRANE HALL ROOF
SCREEN ROOM SUPPLY FAN SF 302
SCREEN ROOM EXHAUST PLENUM
SCREEN ROOM EXHAUST FAN EF 302
1000 CFM
SAMPLING POINT FOR EXPLOSIVE ATMOSPHERE DETECTOR
BALANCING DAMPER SEE DETAIL (TYPICAL 4 PLACES)
8" DRY SEWAGE CONDUIT EXHAUSTS (TYP 4 PLACES)
30"x30" SCREEN ROOM SUPPLY AIR DIFFUSER 6000 CFM EACH (TYP 4 PLACES)
24"x8" SCREEN ROOM EXHAUST DUCT (TYP 11 PLACES)
20"x8" PUMP ROOM EXHAUST DUCT (TYP 4 PLACES)
1000 CFM SUPPLY TO SCREEN ROOM ACCESS HALL
PUMP AND SCREEN ROOM VENTILATION SYSTEM
EQUIPMENT SCHEDULE
SYMBOL
NAME
SF 301 CRANE HALL SUPPLY FAN
SF 302 SCREEN ROOM SUPPLY FAN
SF 303 CABLE ROOM SUPPLY FAN
EF 301 CABLE ROOM EXHAUST FAN
EF 302 SCREEN ROOM EXHAUST FAN
EF 303 LOCKER ROOM EXHAUST FAN
AHF 301 SWITCHGEAR ROOM SUPPLY FAN
AHF 302 CONTROL AREA AIR CONDITIONER
RF 301 RECIRCULATING COOLER 1
RF 302 RECIRCULATING COOLER 2
RAF 301 EAST FAN ROOM FILTER
RAF 302 WEST FAN ROOM FILTER
EAF 301 CONTROL AREA FILTER
CP 301 RECIRCULATING COOLER 1 CHILLED WATER PUMP
CP 302 RECIRCULATING COOLER 2 CHILLED WATER PUMP
CP 303 CRANE HALL CHILLED WATER PUMP
CP 304 SWITCHGEAR ROOM CHILLED WATER PUMP
CP 305 CONTROL AREA CHILLED WATER PUMP
DH 301 CRANE HALL DUCT HEATER
DH 302 SWITCHGEAR ROOM DUCT HEATER
DH 303 CONTROL AREA DUCT HEATER
CC 301 CRANE HALL COOLING COIL
CC 302 SWITCHGEAR ROOM COOLING COIL
CC 303 CONTROL AREA COOLING COIL
LEGEND
CFM
THROAT DIAMETER
SUPPLY AIR DIFFUSER
CFM
DUCT CONNECTION
EXHAUST GRILLE
RETURN AIR GRILLE
SUPPLY AIR GRILLE
NOMINAL DUCT SIZE, INCHES
EXHAUST AIR DUCT
SUPPLY AIR DUCT
VENTILATION SYSTEM
AS CONSTRUCTED
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
R 200 A
RENTON SYSTEM
RENTON SEWAGE TREATMENT PLANT
PUMP BUILDING
VENTILATION SYSTEM
M 320

FIGURE 6.5 VENTILATING AIR RECYCLED THROUGH SCREEN ROOM

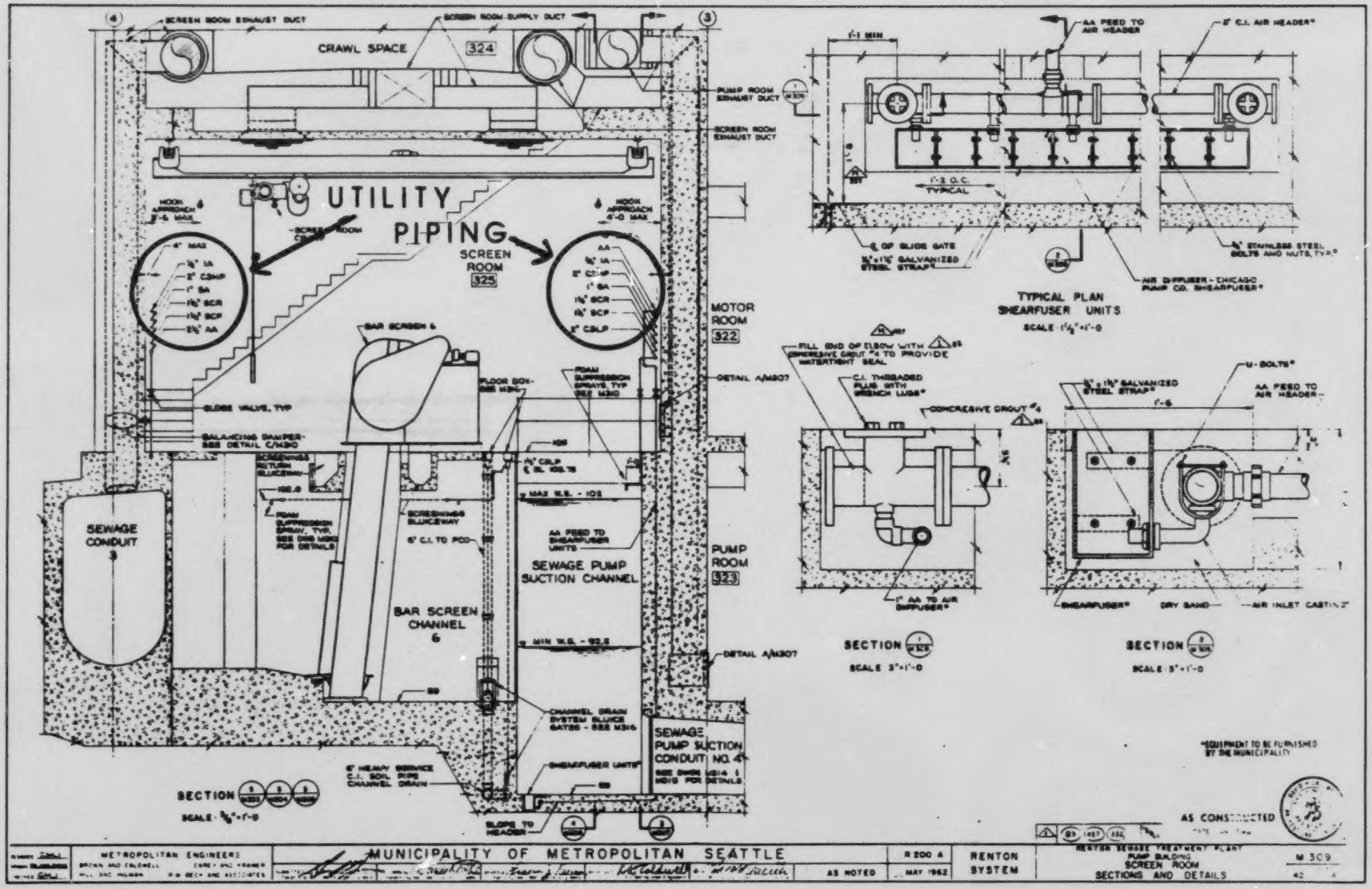
UTILITY PIPING
CRAWL SPACE
324
SCREEN ROOM EXHAUST DUCT
SCREEN ROOM SUPPLY DUCT
PUMP ROOM EXHAUST DUCT
SCREEN ROOM EXHAUST DUCT
SCREEN ROOM
325
MOTOR ROOM
322
PUMP ROOM
323
SEWAGE CONDUIT
BAR SCREEN CHANNEL 6
SEWAGE PUMP SUCTION CHANNEL
SEWAGE PUMP SUCTION CONDUIT NO. 4
AA
IA
CSHP
SA
SCR
SCP
CSLP
GLOBE VALVE, TYP
BALANCING DAMPER - SEE DETAIL C/M310
BAR SCREEN
SCREENINGS SLUICEWAY
FOAM SUPPRESSION SPRAY, TYP.
6" C.I. TO PCD
AA FEED TO SHEARFUSER UNITS
MAX W.S. - 102
MIN W.S. - 92.5
DETAIL A/M307
CHANNEL DRAIN SYSTEM SLUICE GATES - SEE M316
SHEARFUSER UNITS
6" HEAVY SERVICE C.I. SOIL PIPE CHANNEL DRAIN
SLOPE TO HEADER
SECTION
SCALE: 3/8"=1'-0
AA FEED TO AIR HEADER
2" C.I. AIR HEADER
1'-1 MIN
1'-2 O.C. TYPICAL
¢ OF SLIDE GATE
3/8" x 1 1/2" GALVANIZED STEEL STRAP
AIR DIFFUSER - CHICAGO PUMP CO. SHEARFUSER
3/4" STAINLESS STEEL BOLTS AND NUTS, TYP
TYPICAL PLAN SHEARFUSER UNITS
SCALE: 1 1/2"=1'-0
FILL END OF ELBOW WITH CONCRESIVE GROUT #4 TO PROVIDE WATERTIGHT SEAL
C.I. THREADED PLUG WITH WRENCH LUGS
CONCRESIVE GROUT #4
1" AA TO AIR DIFFUSER
SECTION
SCALE: 3"=1'-0
U-BOLTS
AA FEED TO AIR HEADER
3/8" x 1 1/2" GALVANIZED STEEL STRAP
SHEARFUSER
DRY SAND
AIR INLET CASTING
SECTION
SCALE: 3"=1'-0
EQUIPMENT TO BE FURNISHED BY THE MUNICIPALITY
AS CONSTRUCTED
METROPOLITAN ENGINEERS
BROWN AND CALDWELL
CAREY AND KRAMER
HILL AND INGMAN
R.W. BECK AND ASSOCIATES
MUNICIPALITY OF METROPOLITAN SEATTLE
AS NOTED
R 200 A
MAY 1962
RENTON SYSTEM
RENTON SEWAGE TREATMENT PLANT
PUMP BUILDING
SCREEN ROOM
SECTIONS AND DETAILS
M 309

FIGURE 6.6 PROPER LOCATION OF UTILITY PIPES ABOVE SEWAGE CONDUIT

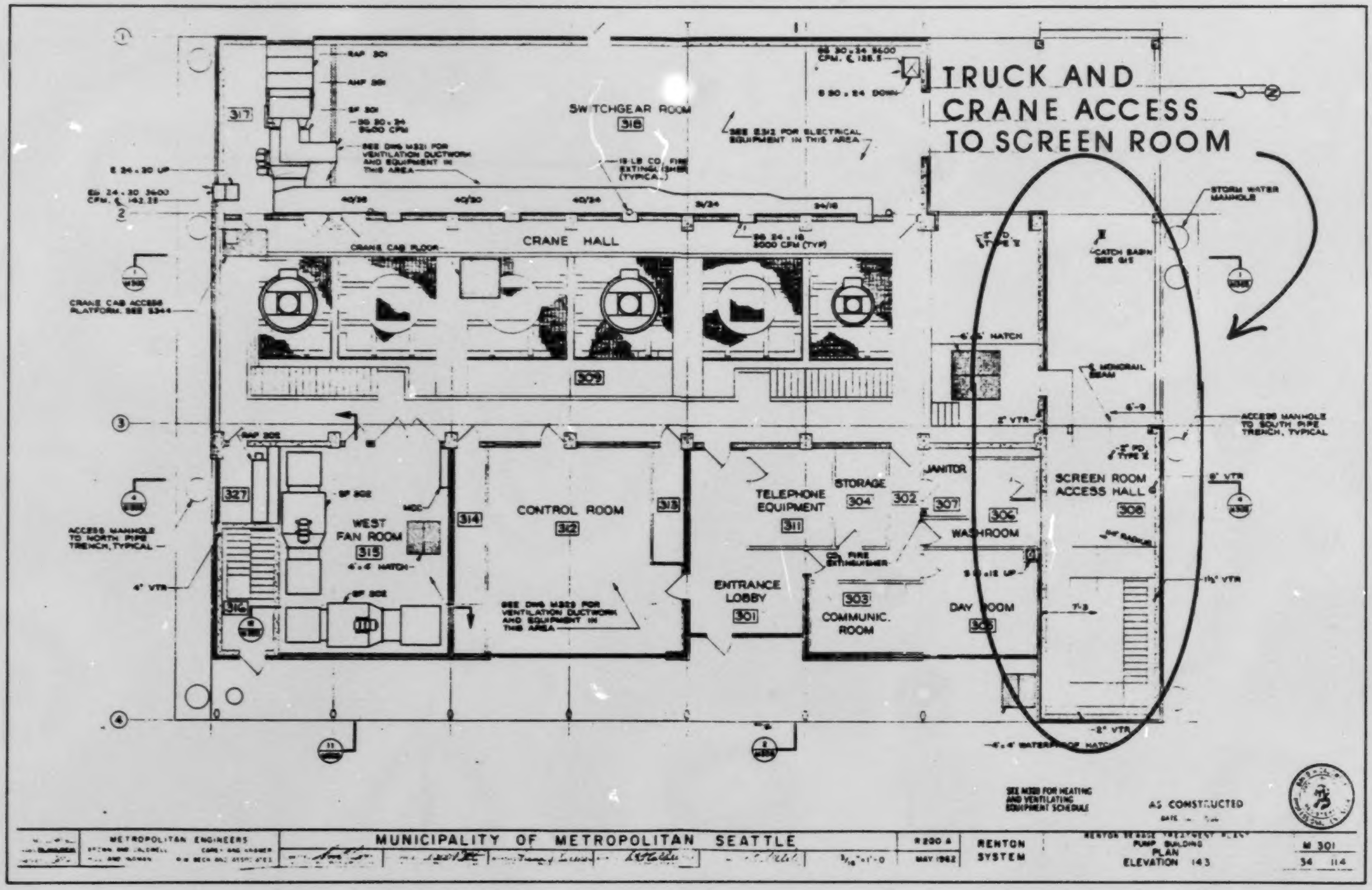
TRUCK AND CRANE ACCESS TO SCREEN ROOM
SWITCHGEAR ROOM
318
317
CRANE HALL
CRANE CAB FLOOR
309
SEE E312 FOR ELECTRICAL EQUIPMENT IN THIS AREA
STORM WATER MANHOLE
CATCH BASIN SEE G15
MONORAIL BEAM
ACCESS MANHOLE TO SOUTH PIPE TRENCH, TYPICAL
ACCESS MANHOLE TO NORTH PIPE TRENCH, TYPICAL
CRANE CAB ACCESS PLATFORM. SEE S344
WEST FAN ROOM
315
316
327
314
CONTROL ROOM
312
313
ENTRANCE LOBBY
301
TELEPHONE EQUIPMENT
311
STORAGE
304
302
JANITOR
307
306
WASHROOM
303
COMMUNIC. ROOM
DAY ROOM
305
SCREEN ROOM ACCESS HALL
308
SEE DWG M322 FOR VENTILATION DUCTWORK AND EQUIPMENT IN THIS AREA
SEE DWG M321 FOR VENTILATION DUCTWORK AND EQUIPMENT IN THIS AREA
SEE M322 FOR HEATING AND VENTILATING EQUIPMENT SCHEDULE
AS CONSTRUCTED
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
R200 A
MAY 1962
RENTON SYSTEM
RENTON SEWAGE TREATMENT PLANT
PUMP BUILDING
PLAN
ELEVATION 143
M 301
34 114

FIGURE 6.7 PROPER TRUCK AND CRANE ACCESS TO SCREEN ROOM

B. Influent Channels

The head of a wastewater treatment plant receives both raw sewage and any return flows generated at the plant. It is important that both of these flows be monitored since both quality and quantity of influent determines the efficiency of plant operation. For flexibility, operators should be able to monitor return flows and raw sewage separately. Return flows from all unit processes should be combined and directed into the plant influent at a common point. This permits metering and sampling of all return flows in one location (see Figure 6.8). There should also be a by-pass line that will direct recycled wastewater directly into the influent channel if the metering device fails. Raw sewage must be sampled upstream of the recycled flow return points. Combined raw wastewater and return flows may be sampled in the screen room, or off the discharge side of the influent pumps. This latter location allows the operator to take advantage of the pump pressure to make sampling easier. By sampling in these locations, the operator will know the actual loading to the plant, including any recycle that may be brought to the head of the plant.

In facilities with special monitoring requirements, sewage may be diverted from the influent pumps and through another channel for sampling. For example, in Sacramento, California, there were pH and conductivity fluctuations in the raw sewage due to a combined domestic and industrial load. A trough received sewage from the influent pump and discharged it over a rectangular weir. The weir was lifted once per shift to remove debris. Conductivity and pH probes were placed in the trough. This type of system is easy to monitor, maintain and keep clean.

Flow division in influent channels provides for flexibility, both as plant load increases and as flow fluctuates during wet and dry periods. The design should insure that there is a smooth inlet flow distribution and a means for equalizing flow volume to each influent channel. Solids distribution among all channels must be equal. Agitation should be provided if the natural distribution is in question. Devices such as shearfusers, recessed in the channel bottom, are ideal for this purpose. A minimum velocity of 1.5 feet/sec. is necessary to prevent solids deposition.

Influent channels should be designed to accommodate future plant expansion. This can be done by either constructing extra channels that will be put on line as flow increases or by designing channels that routinely can handle higher flows.

At Sunnyvale, California, three bar-screened influent channels were built with the center acting as back-up for the other two (see Figure 6.9). At the Renton wastewater treatment plant in Seattle, Washington, the initial flow was 12 mgd with 124 mgd as design capacity. Four influent channels were constructed downstream from an 11-foot diameter sewer pipe (see Figure 6.10). However, two of the channels were blocked off and would be put into use during future plant expansions (see Figure 6.11). Each of the four conduits was fitted with two bar screens; one acting as back-up. At the Sacramento Regional Plant, all three influent conduits were in use when the plant opened (115 mgd); but these channels were designed, hydraulically, to handle up to 300 mgd. For flexibility, flow from each of these channels could be further

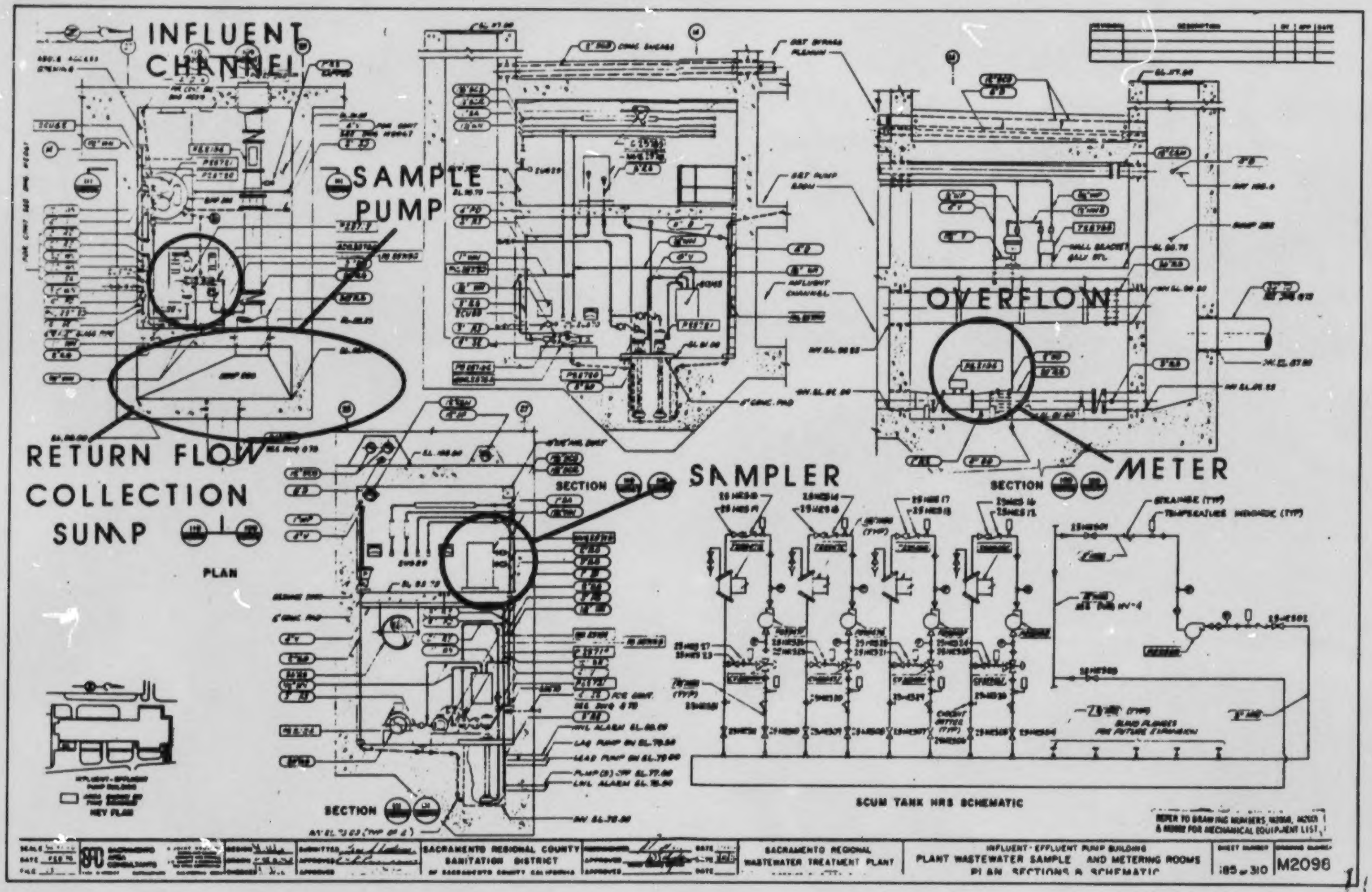
INFLUENT CHANNEL
SAMPLE PUMP
RETURN FLOW COLLECTION SUMP
PLAN
OVERFLOW
SECTION
SAMPLER
METER
SECTION
SECTION
SCUM TANK HRS SCHEMATIC
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
INFLUENT-EFFLUENT PUMP BUILDING
PLANT WASTEWATER SAMPLE AND METERING ROOMS
PLAN, SECTIONS & SCHEMATIC
185 of 310
M2098

FIGURE 6.8 LOCATION OF SAMPLING DEVICES

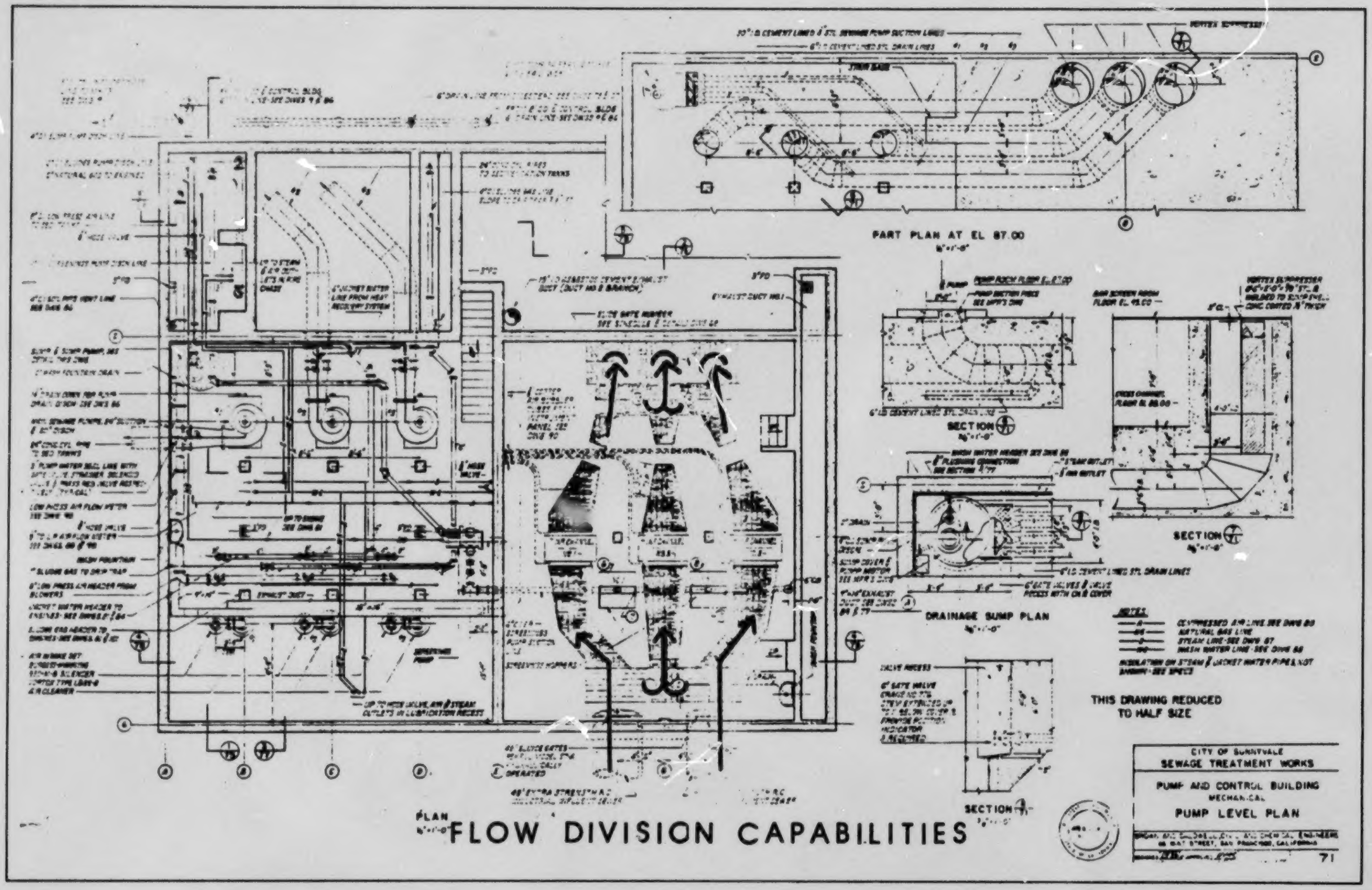
PART PLAN AT EL 87.00
SECTION
DRAINAGE SUMP PLAN
SECTION
THIS DRAWING REDUCED TO HALF SIZE
CITY OF SUNNYVALE
SEWAGE TREATMENT WORKS
PUMP AND CONTROL BUILDING
MECHANICAL
PUMP LEVEL PLAN
71
PLAN
FLOW DIVISION CAPABILITIES

FIGURE 6.9 CENTER CHANNEL BACK-UP

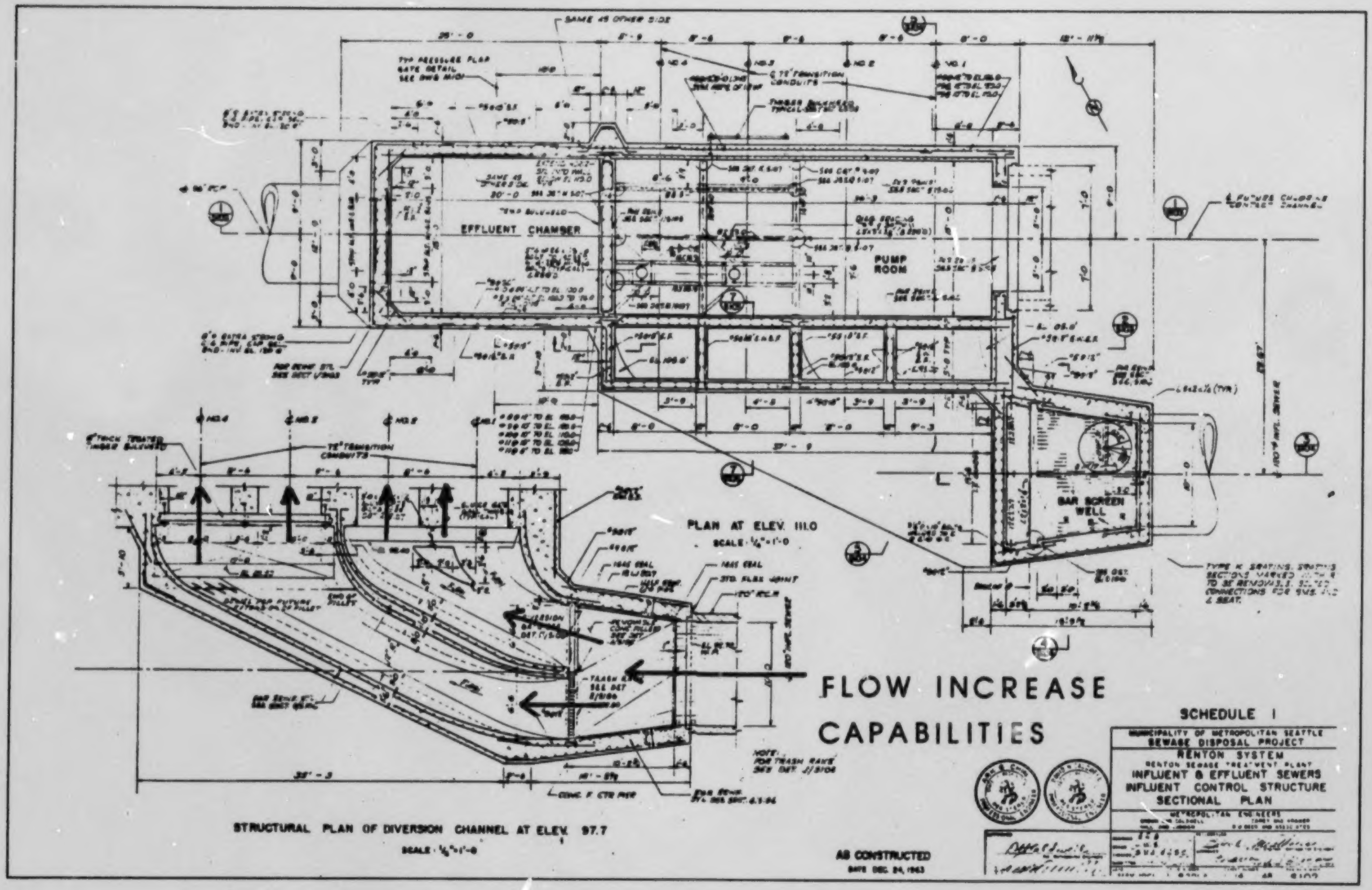
EFFLUENT CHAMBER
PUMP ROOM
BAR SCREEN WELL
PLAN AT ELEV. 111.0
SCALE · 1/4"=1'-0
FLOW INCREASE
CAPABILITIES
STRUCTURAL PLAN OF DIVERSION CHANNEL AT ELEV. 97.7
SCALE · 1/4"=1'-0
SCHEDULE I
MUNICIPALITY OF METROPOLITAN SEATTLE
SEWAGE DISPOSAL PROJECT
RENTON SYSTEM
RENTON SEWAGE TREATMENT PLANT
INFLUENT & EFFLUENT SEWERS
INFLUENT CONTROL STRUCTURE
SECTIONAL PLAN
METROPOLITAN ENGINEERS
AS CONSTRUCTED
DATE DEC. 24, 1963

FIGURE 6.10 REDUNDANT INFLUENT CHANNELS FOR FUTURE GROWTH

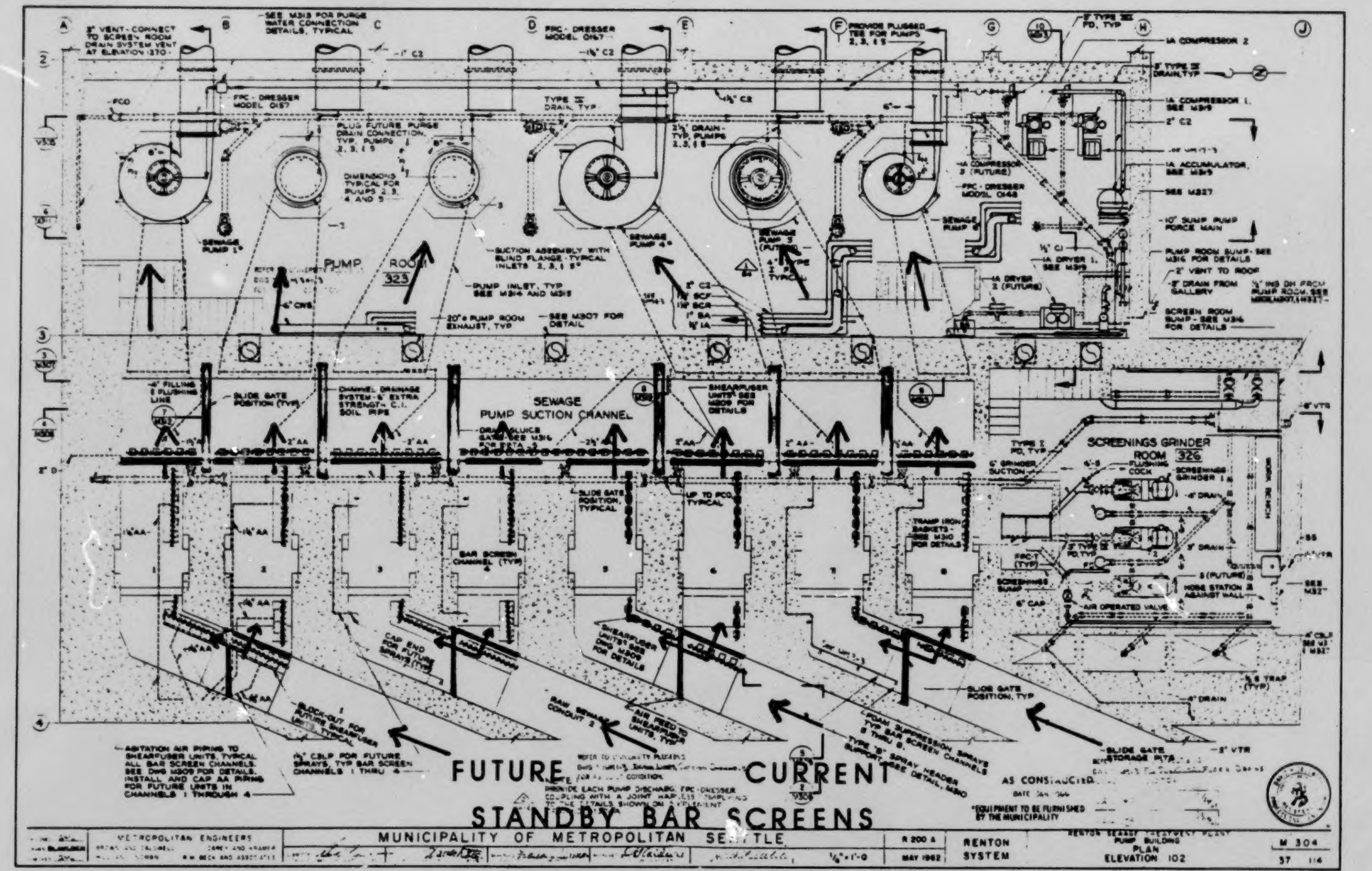
PUMP ROOM 323
SEWAGE PUMP SUCTION CHANNEL
SCREENINGS GRINDER ROOM 326
SEWAGE PUMP 1
SEWAGE PUMP 4
FUTURE
CURRENT
STANDBY BAR SCREENS
AS CONSTRUCTED
EQUIPMENT TO BE FURNISHED BY THE MUNICIPALITY
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
RENTON SYSTEM
PUMP BUILDING
PLAN
ELEVATION 102
MAY 1962
M 304

FIGURE 6.11 STANDBY SCREENS FOR FUTURE GROWTH

divided into two bar-screened conduits, which were upstream of six influent pumps (see Figure 6.12).

A common failing in many plants is the use of sharp right angle bends immediately ahead of flow division arrangements. Unless there is an ample straight run ahead of a splitting tee and head losses in each branch of the tee, the flow will not divide evenly. Particular care should be taken in channel and piping arrangements immediately upstream of Parshall flumes and flow meters. It is good practice to provide a straight run ahead of any metering equipment to ensure accurate flow measurement.

C. Bar Screens and Comminutors

Screening is generally the first unit operation encountered in the wastewater treatment train. Depending upon the application, there are several types of screening devices in common use. Bar racks or screens are used as the first unit in a treatment plant or pump station to remove large debris which might damage or clog downstream pumps or equipment. Fine screens have been used for pretreatment or primary treatment, and recently microscreens have been used to upgrade secondary effluents. Comminuting devices are used to grind solid material in the wastewater without removing it from the flow.

Design considerations for screening devices will vary with the application. However, there are several factors which should be considered. The size of the openings is a function of the size of particles to be removed. For coarse screens, the size is based on the particle removal needed to protect downstream equipment. With fine screens, the size of the openings is based on the particle size, distribution in the wastewater and the degree of removal desired. The spacing of the cutting bars in comminuting devices is governed by the size of the largest particle which can be allowed to pass.

The hydraulic loading or velocity through the device affects the removal efficiency. For coarse screens, the removal efficiency should be maximized, but care should be taken to avoid velocity reductions which cause sedimentation in the channels. With fine screens the hydraulic loading is governed by the solids in the feed, the desired efficiency and head loss considerations. In designing any screening device, the available head and the overall hydraulic gradient of the treatment facility should be considered.

In addition to the general considerations described above, the design of microscreens must take into account the diameter and submergence of the drum, the drum speed, and the backwash flow and pressure.

1. Bar Screens

Since bar screens are the first treatment process to deal with incoming sewage, they must receive a great deal of maintenance and yet are unpleasant to service. Thus, it is important that the Design Engineer make the maintenance and operation of the bar screens as easy as possible for plant personnel.

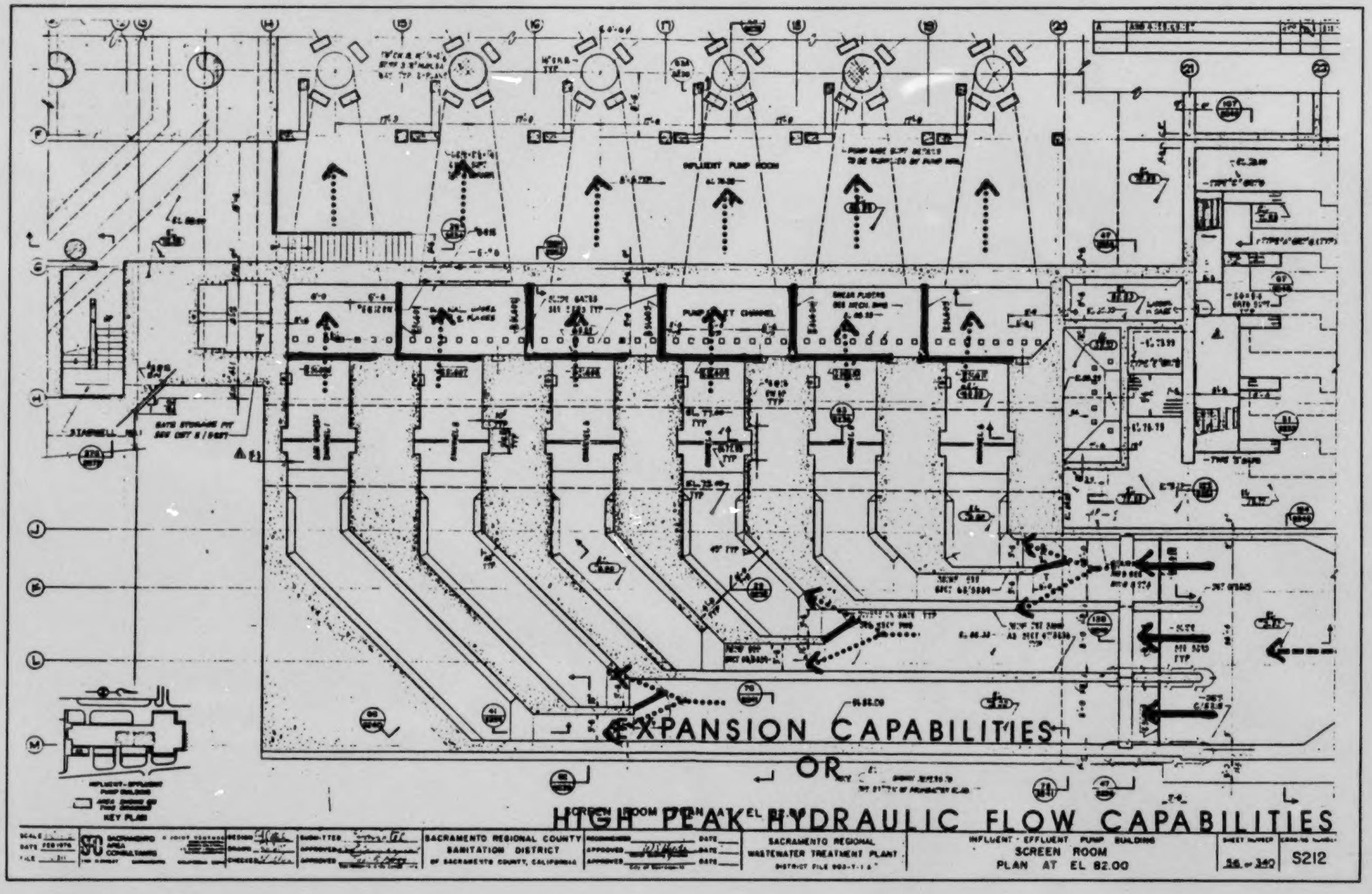
EXPANSION CAPABILITIES
OR
HIGH PEAK HYDRAULIC FLOW CAPABILITIES
INFLUENT PUMP ROOM
PUMP OUTLET CHANNEL
KEY PLAN
SACRAMENTO REGIONAL COUNTY
SANITATION DISTRICT
OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL
WASTEWATER TREATMENT PLANT
INFLUENT - EFFLUENT PUMP BUILDING
SCREEN ROOM
PLAN AT EL 82.00
S212

FIGURE 6.12 FLOW DIVISION CAPABILITIES FOR FLEXIBILITY

For maintenance purposes, operators should be able to isolate and drain the channel area around bar screens. This can be done using slide gates upstream and downstream of the screens (see Figure 6.12). A drain should be provided between the gates up against the wall of the channel. Placement at this position will prevent debris from collecting on drain hardware. A straight channel ahead of the screen insures a good velocity distribution across the screen and maximum effectiveness of the device. Failure to use a straight approach channel may allow a large percentage of the flow to pass through one side of the screen. Maximum flow velocities in the influent channel should be limited through the screen at peak flows to prevent screenings carryover and to reduce head losses.

Mechanical bar screens should be of heavy duty design with large sprockets and the heaviest weight chain available. The back return-front clean type of bar screen is preferred. Where mechanically operated screening or comminuting devices are used, auxiliary manually cleaned screens should be provided. Designs should include provisions for automatic diversion of the entire wastewater flow through auxiliary screens should the mechanical units fail.

Automatic control of mechanical bar screens is desirable as continuous running causes excess wear. Automated control allows the bar screen to function by a time clock or when the differential head loss increases above a certain minimum value. Operation by a time clock, for a period adjustable by the operator, is recommended with either a high-water or high-differential contact that will place the rack in continuous operation when needed during periods of peak loading.

Adequate facilities must be provided for removal, handling, storage and disposal of screenings. Hand cleaned screening devices should be provided with a platform from which the operator may rake screenings easily and safely. Suitable drainage facilities should be provided for both the platform and storage areas. If the screening device is to be placed in a deep pit or channel, then approaches from above should be wide enough for comfortable access and suitable for the elevation of collected materials.

Water can serve the dual function of removing screenings from the rack and cleaning it at the same time. Water can then be used to sluice screenings to the grinders. Grinders must be protected from tramp metal and rocks by using a magnet and hopper to remove these materials. Screen discharges should be located at ground level, if possible.

For day to day operation, screenings should be removed from the waste stream and processed separately. This reduces both sludge operation requirements and maintenance on channels, equipment and downstream piping. There should be flexibility to return ground screenings to the plant flow ahead of the bar screens as shown in Figure 6.13.

Screenings may be dewatered using either fixed or rotary screens or by centrifuges if the screenings are to be incinerated. If incinerated, it is advisable to mix dewatered screenings with sludge. This aids the burning process as the volatile solids content of screenings can be

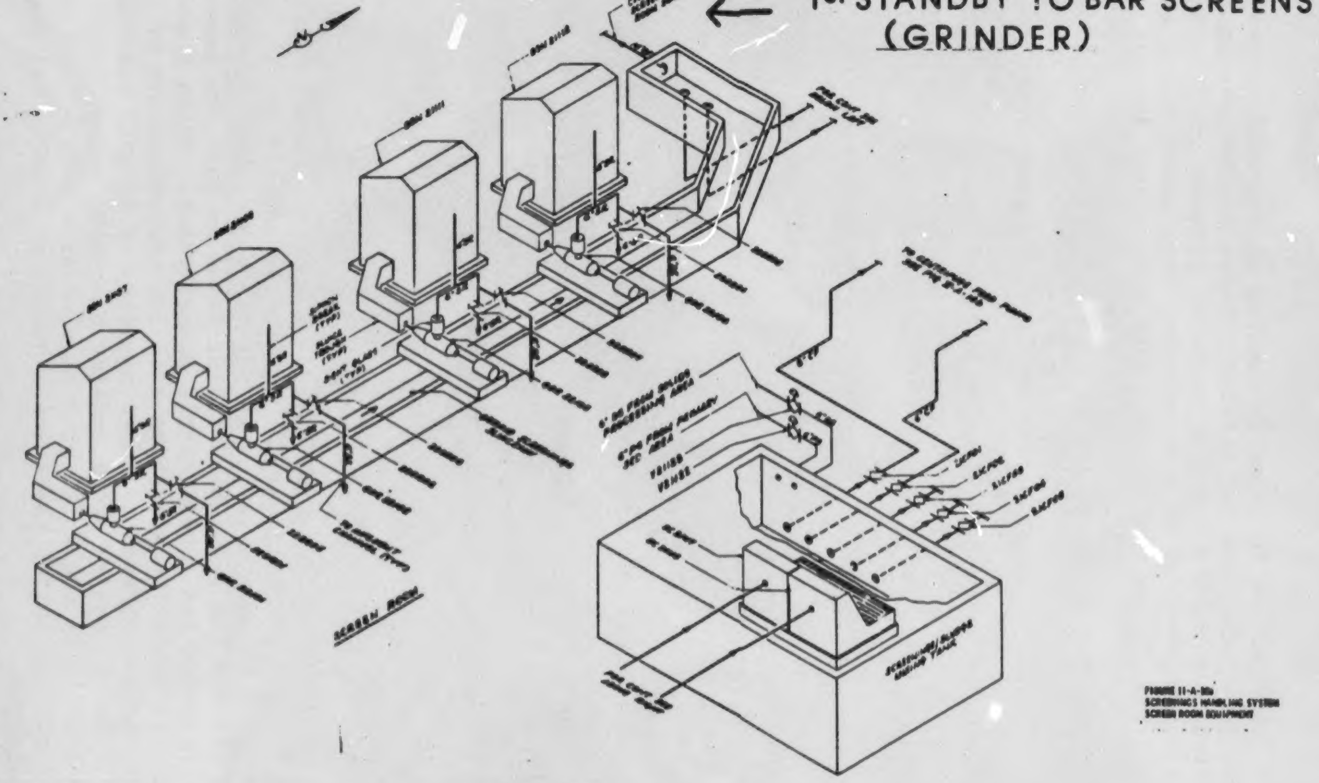
1st STANDBY TO BAR SCREENS
(GRINDER)
SCREEN ROOM
FIGURE II-A-8b
SCREENINGS HANDLING SYSTEM
SCREEN ROOM EQUIPMENT

FIGURE 6.13 STANDBY TO BAR SCREENS

quite variable. No matter which method is used for dewatering and disposal, flexibility should be provided in the form of standby dewatering and transfer equipment. The equipment should allow the operator to dispose of the waste to an incinerator or to a hopper for landfill disposal (see Figure 6.14).

2. Motors

Comminutors function by cutting up materials in-stream that would normally be retained on bar screens. These divided wastes are then removed downstream in either the grit tanks or primary settling tanks. If comminutors are not preceded by grit removal, then gravel traps should be provided to protect the cutting teeth. When maintenance becomes necessary, the comminutors should be able to be isolated with slide gates, and cranes should be provided to remove the device.

If multiple comminutors are not employed, a by-pass screen should be provided. The overflow to the by-pass channel should occur when the influent channel is flowing at a depth which corresponds to the design flow through the comminutor. If flooding of the immediate area can occur, then an elevated motor for the comminutor is advisable.

3. Effects of Storm Flows in Combined Sewers

The design of treatment plants to serve combined sewer systems adds an additional dimension to flow and load variations arriving at the plant as a result of storms. A large storm, particularly one that occurs after a long period of dryness, can result in tremendous quantities of screenings and grit arriving at the treatment plant in a very short period of time. Unless mechanically-cleaned screens, comminutors and grit removal equipment are designed to handle these quantities of materials, failures can be expected to occur. Comminutors, in particular, often do not have the cutting capacity to handle sudden slug loadings of screenings, leaves and other debris flushed from the sewers. Thus, mechanically-cleaned bar screens are preferable in combined sewer systems. The operator should not dispose of ground screenings in the flow if the screenings can be disposed of directly.

D. Grit Collectors

1. Theoretical Considerations

Gravitational sedimentation is used in a number of solids/liquid separation processes throughout the wastewater treatment sequence. The rate of sedimentation is dependent upon the interactions between particles and the suspending fluid; these in turn are dependent on the particle concentration and interparticle cohesiveness. Class I sedimentation is the type of sedimentation resulting when low concentrations of non-flocculant particles, such as those encountered in grit removal, separate from a liquid. In the design of wastewater treatment units, Class I sedimentation principles apply to the design of grit removal facilities. In designing grit removal units, there are a number of theoretical factors which should be considered.

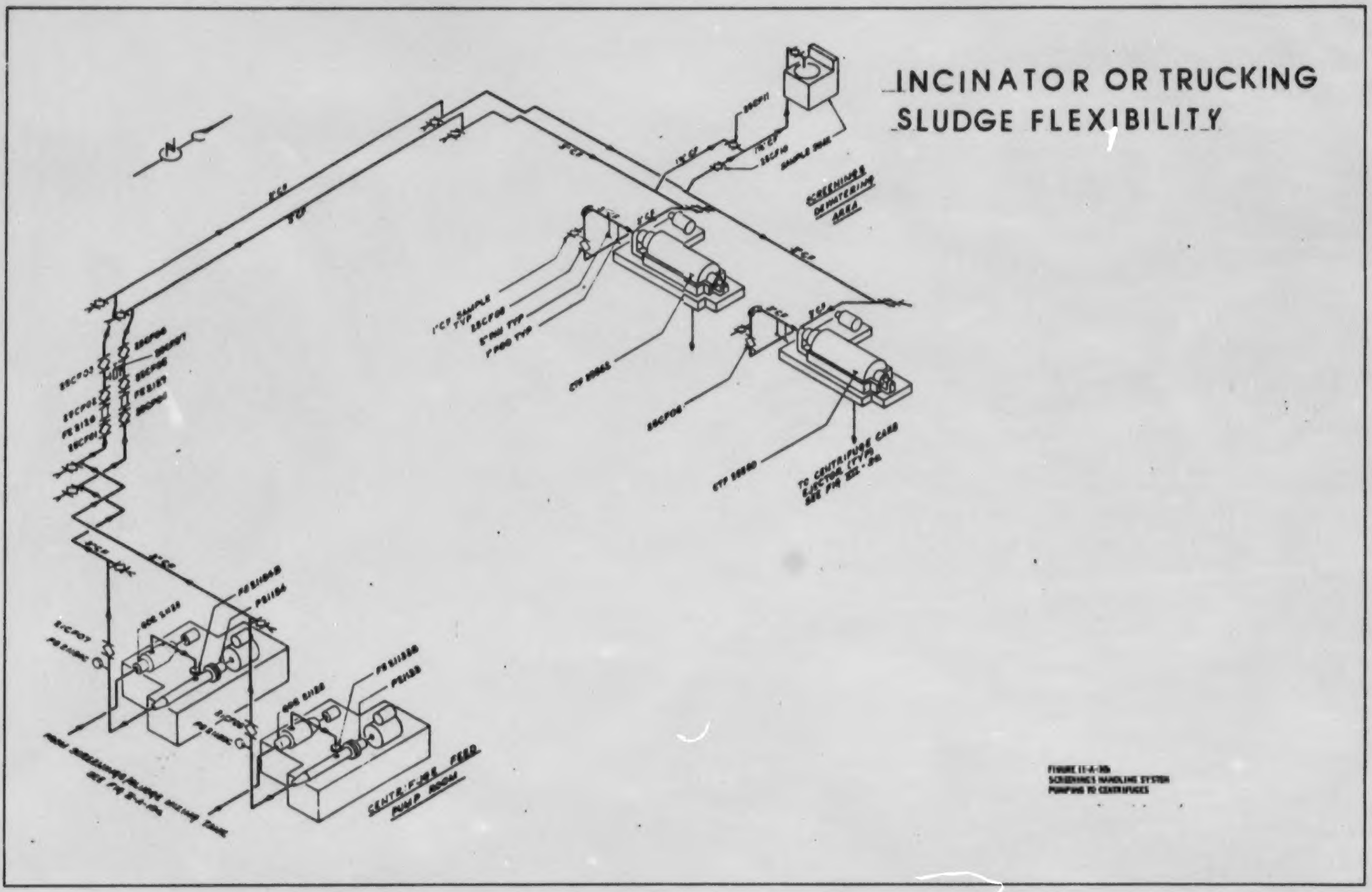
INCINATOR OR TRUCKING
SLUDGE FLEXIBILITY
N
SCREENINGS DEWATERING AREA
SAMPLE SINK
1" CP SAMPLE TYP
CENTRIFUGE FEED PUMP ROOM
TO CENTRIFUGE CAKE EJECTOR (TYP)
FIGURE II-A-30
SCREENINGS HANDLING SYSTEM
PUMPING TO CENTRIFUGES

FIGURE 6.14 FLEXIBILITY PROVIDED IN SLUDGE HANDLING

The settling of discrete particles is governed by Stokes' Law.

$$V = \frac{4g\ (P_s - P_e)\ D}{3\ C_D\ P_e}$$

Where:

V = Terminal settling velocity

g = Gravitational constant

P_s & P_e = Densities of solid & liquid respectively

D = Diameter of particle (effective diameter)

$$C_D = \frac{24\ \mu}{V\ D\ P_e}$$

Where:

μ = Viscosity

Substituting:

$$V = \frac{g\ (P_s - P_e)\ D^2}{18\ \mu}$$

Thus, for discrete particles, the settling velocity is a function of particle diameter and density of the fluid.

Theoretically, any particle which has a settling velocity greater than the overflow rate of the settling tank will be removed completely. However, factors such as turbulence and solids accumulation complicate the theory. Consider an "idealized" basin. In this case, any particle which will settle through the settling zone before reaching the outlet zone will be removed completely. Particles with lower settling velocities will be removed partially depending on their initial depth when passing into the settling zone. Therefore, the efficiency of Class I sedimentation is independent of tank depth and retention time and is a function only of overflow rate.

Based on the theory of Class I sedimentation, there are a number of factors which should be considered in the design of grit removal facilities. The overflow rate should provide complete removal of a specified particle size. Particles with settling velocities, Vj, less than the design, Vd, will be removed in proportion to the ratio of the two velocities, Vj/Vd.

Thus, the total removal efficiency can be calculated from a sieve analysis or from lab settling data. Dimensions of basins should be sufficient to avoid scouring of previously deposited materials. Flow-through velocities are regulated by a control section or weir.

2. Operational Considerations

It is desirable to locate grit tanks ahead of raw sewage pumps to protect them from abrasion and reduce maintenance. However, at some installations this may involve placing the tanks at a considerable depth. Thus, it may be more economical to locate the grit chambers downstream of pumps, recognizing that the pumps will be subject to more maintenance than if located behind the grit tanks (see Figure 6.15).

The design of grit tanks depends on the type selected, on whether or not mechanical grit-removal equipment is provided and on the requirements of the selected grit removal equipment. In recent years, the majority of grit chamber installations having a capacity in excess of 1.5 mgd have been provided with mechanical cleaning equipment.

The aerated grit chamber is the most popular design used at the present time. The velocity of roll in the tank governs the size of particles that will be removed. Air introduction should be made along the side of each tank. Liquid flow through the tank should complement air roll in the transport of grit to removal hoppers. The air distribution pattern should be designed to provide a spiral roll pattern in the tank.

For operational control, the ability to vary the air rate with diffusers is a desirable feature. This permits control of the rolling pattern, or grit removal efficiency, and of the quantity of putrescible matter present in the grit. It is recommended that swing diffusers be used in grit tanks as they provide a fine rate of aeration and they can be easily removed for maintenance.

Foam suppression and scum removal units should be provided for each grit tank. Foam suppression can be accomplished using water sprays with the capacity for chemical addition (see Figure 6.16). Manual stripping of scum is usually adequate.

Multiple hoppers and grit removal pumps should be provided for each grit tank. Each hopper should have air and water for agitation at the suction end of the grit pump (see Figure 6.17). For intermittent pump operation, the air agitation is run for about five minutes. The pump is then started, and the air shut off. Water agitation then continues while the grit pump is on. Thus, the air quickly stirs up the grit, but is shut off to avoid interfering with centrifugal pump action. The water then maintains the grit in suspension. On tanks with multiple hoppers, the first generally receives more grit than the rest. For this reason, the first hopper should be provided with its own cyclone separator, and the grit pump should be run continuously. The remaining hoppers can share a common separator and be run on an intermittent basis.

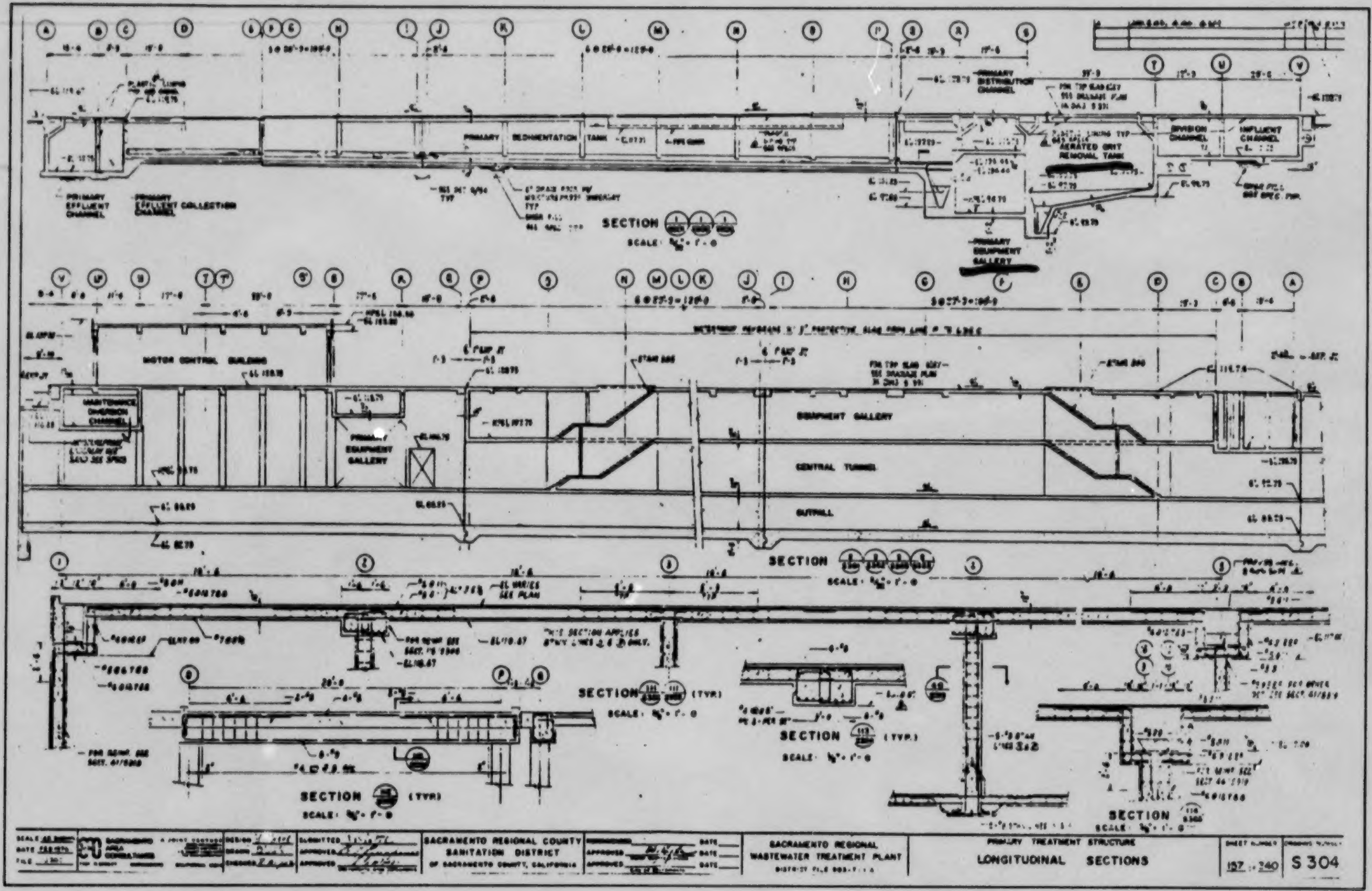
PRIMARY SEDIMENTATION TANK
AERATED GRIT REMOVAL TANK
DIVISION CHANNEL
INFLUENT CHANNEL
PRIMARY DISTRIBUTION CHANNEL
PRIMARY EFFLUENT CHANNEL
PRIMARY EFFLUENT COLLECTION CHANNEL
PRIMARY EQUIPMENT GALLERY
SECTION
MOTOR CONTROL BUILDING
MAINTENANCE DIVERSION CHANNEL
EQUIPMENT GALLERY
CENTRAL TUNNEL
OUTFALL
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
PRIMARY TREATMENT STRUCTURE
LONGITUDINAL SECTIONS
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FIGURE 6.15 GRIT CHAMBERS LOCATED DOWNSTREAM OF PUMPS TO LESSEN REQUIRED DEPTH

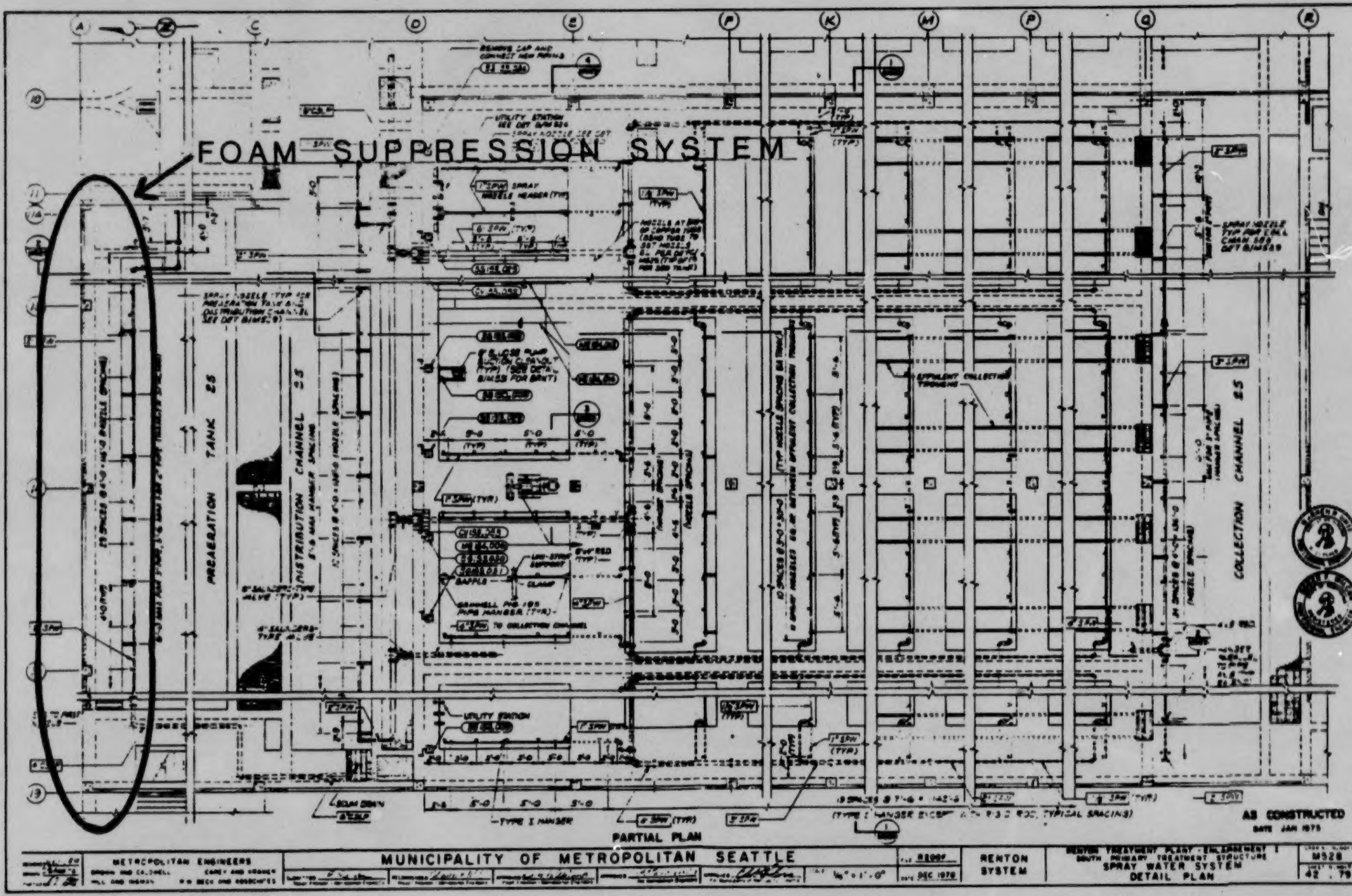

FOAM SUPPRESSION SYSTEM
PREAERATION TANK 25
DISTRIBUTION CHANNEL 25
COLLECTION CHANNEL 25
UTILITY STATION
PARTIAL PLAN
AS CONSTRUCTED
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
RENTON SYSTEM
SPRAY WATER SYSTEM
DETAIL PLAN

FIGURE 6.16 WATER SPRAY FOAM SUPPRESSION

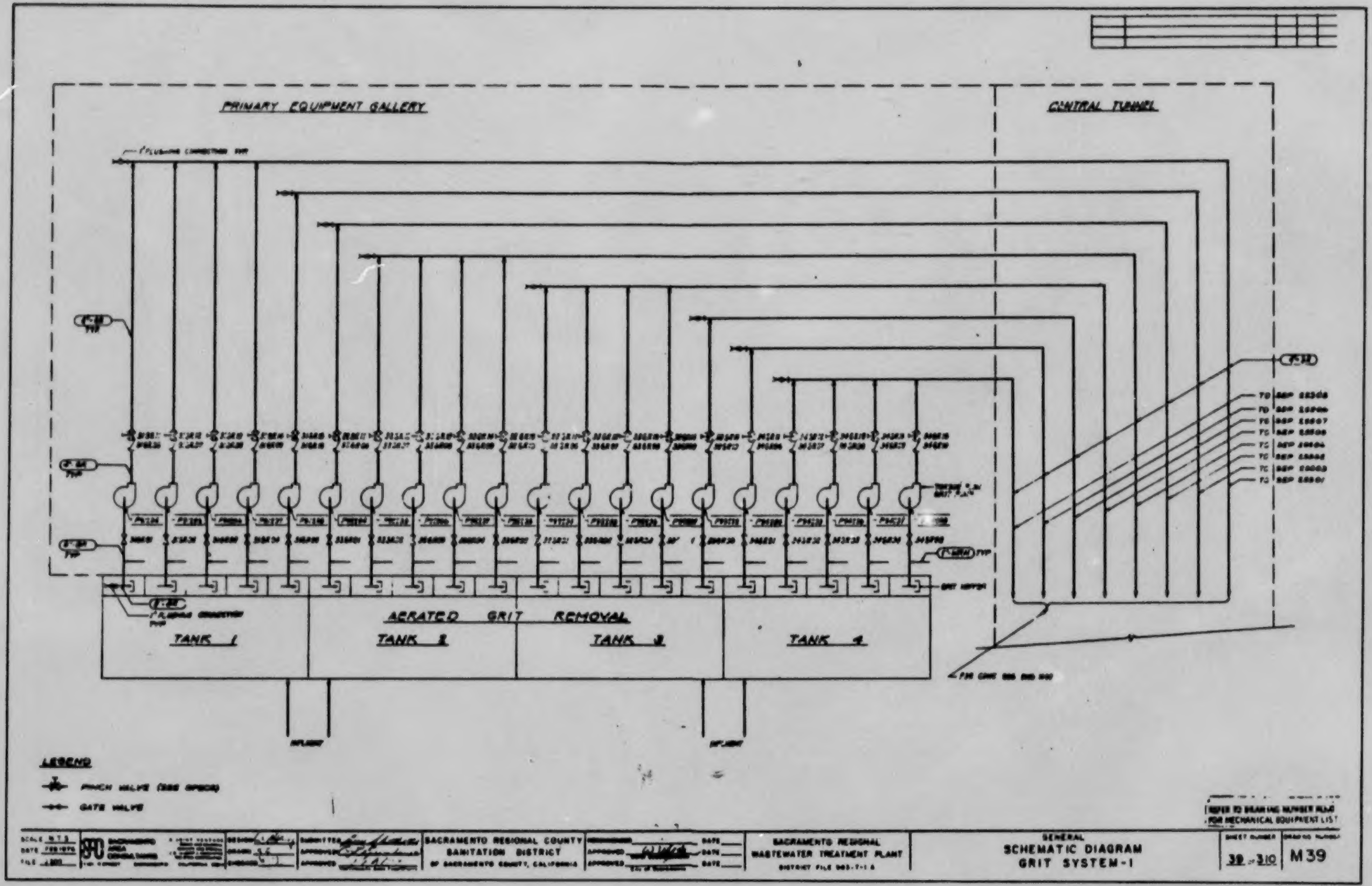

PRIMARY EQUIPMENT GALLERY
CENTRAL TUNNEL
AERATED GRIT REMOVAL
TANK 1
TANK 2
TANK 3
TANK 4
INFLUENT
INFLUENT
GRIT HOPPER
LEGEND
PINCH VALVE (SEE SPECS)
GATE VALVE
REFER TO DRAWING NUMBER M40 FOR MECHANICAL EQUIPMENT LIST
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
GENERAL
SCHEMATIC DIAGRAM
GRIT SYSTEM-1
SHEET NUMBER
39 of 310
DRAWING NUMBER
M39

FIGURE 6.17 MULTIPLE HOPPERS AND GRIT REMOVAL PUMPS

Grit pumps should operate sequentially under control of a timing program that provides for variable frequency and duration of operation. Interlock agitation should be provided, with pump control to start agitation prior to pump start and to stop agitation on a time sequence with the grit pumps (see Figure 6.18).

Pumps used in grit removal should be wear and clog resistant. Diaphragm pumps are especially useful in this regard. Adjustable pitch sheaves (± 10 percent design speed) can be used on pump drives to allow optimum pump speed adjustment at startup without requiring sheave and belt replacement. A tapered plug valve with hydraulic controls may be used on grit pumps instead of a check valve to avoid wear and tear on the valve. To facilitate changing pumps, there should be no interconnections between pumps. Additionally, with combined suction, a pump that is not being used may become clogged and not function when needed.

The use of a gallery beneath grit tanks to house the grit pumps is recommended. This will allow placement of the pumps underneath and close by the grit tank drains (see Figure 6.19). Grit can be difficult to remove, so it is important to keep the grit tanks and pumps as close to each other as possible to maintain a good positive head on the pumps. Use rectangular grit and primary sedimentation tanks for ease of pump placement. This will permit the pumps to get good suction on the grit and sludge, and it can outweigh the disadvantages of using rectangular tanks.

If the pump suction line is below the liquid level in the grit tank, then the line should be carried all the way to the top of the tank for ease of maintenance. The grit removal system should have no 90 degree elbows in the piping and long, vertical pipe runs should be avoided. Long radius elbows and flushing connections will help alleviate pipe blockage and wear problems. Mechanical couplings should be used at all pipe fittings.

The settled waste is pumped to a grit dewatering device, which in most cases is a cyclonic separator (see Figure 6.20). Two grit pipes and two grit dewatering units should be provided for each grit tank. Overflow from the cyclone separators should be directed into the plant flow ahead of the grit tanks to catch any remaining grit. However, lighter material may not be captured in the tank or removed by the separator. This material may back through the system over and over again. This can be avoided by placing a 1/8-inch hydrasieve in the overflow to catch the lighter debris.

The hydraulic handling of grit decreases costs and increases ease of handling. This is especially true if the debris is to be hauled off. Hydrasieves should provide sufficient dewatering for such a system.

Grit chambers in deep pits should be provided with mechanical equipment for hoisting grit to ground level. Such chambers should have a stairway with adequate ventilation and lighting. Hard surfaces with drains should be located in grit handling areas. An adequate supply of water under pressure must be provided in grit chambers and grit handling areas.

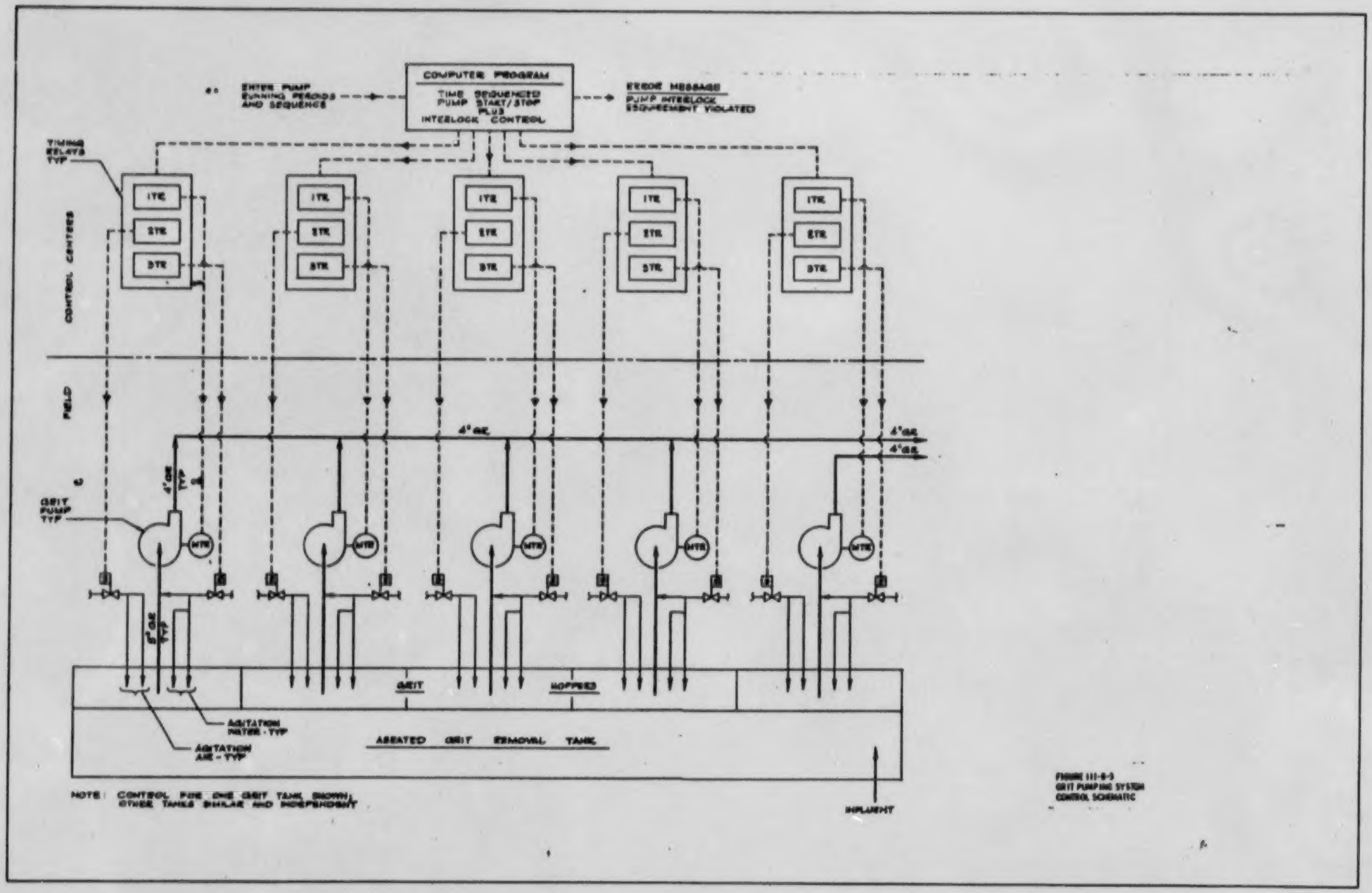

COMPUTER PROGRAM
TIME SEQUENCED PUMP START/STOP PLUS INTERLOCK CONTROL
ENTER PUMP RUNNING PERIODS AND SEQUENCE
ERROR MESSAGE
PUMP INTERLOCK REQUIREMENT VIOLATED
TIMING RELAYS TYP
ITR
STR
DTR
CONTROL CENTERS
FIELD
4" GR
GRIT PUMP TYP
MTR
GRIT
HOPPERS
AGITATION WATER - TYP
AGITATION AIR - TYP
AERATED GRIT REMOVAL TANK
INFLUENT
NOTE: CONTROL FOR ONE GRIT TANK SHOWN, OTHER TANKS SIMILAR AND INDEPENDENT
FIGURE III-8-3
GRIT PUMPING SYSTEM
CONTROL SCHEMATIC

FIGURE 6.18 AUTOMATED CONTROL FOR GRIT PUMPING SYSTEM

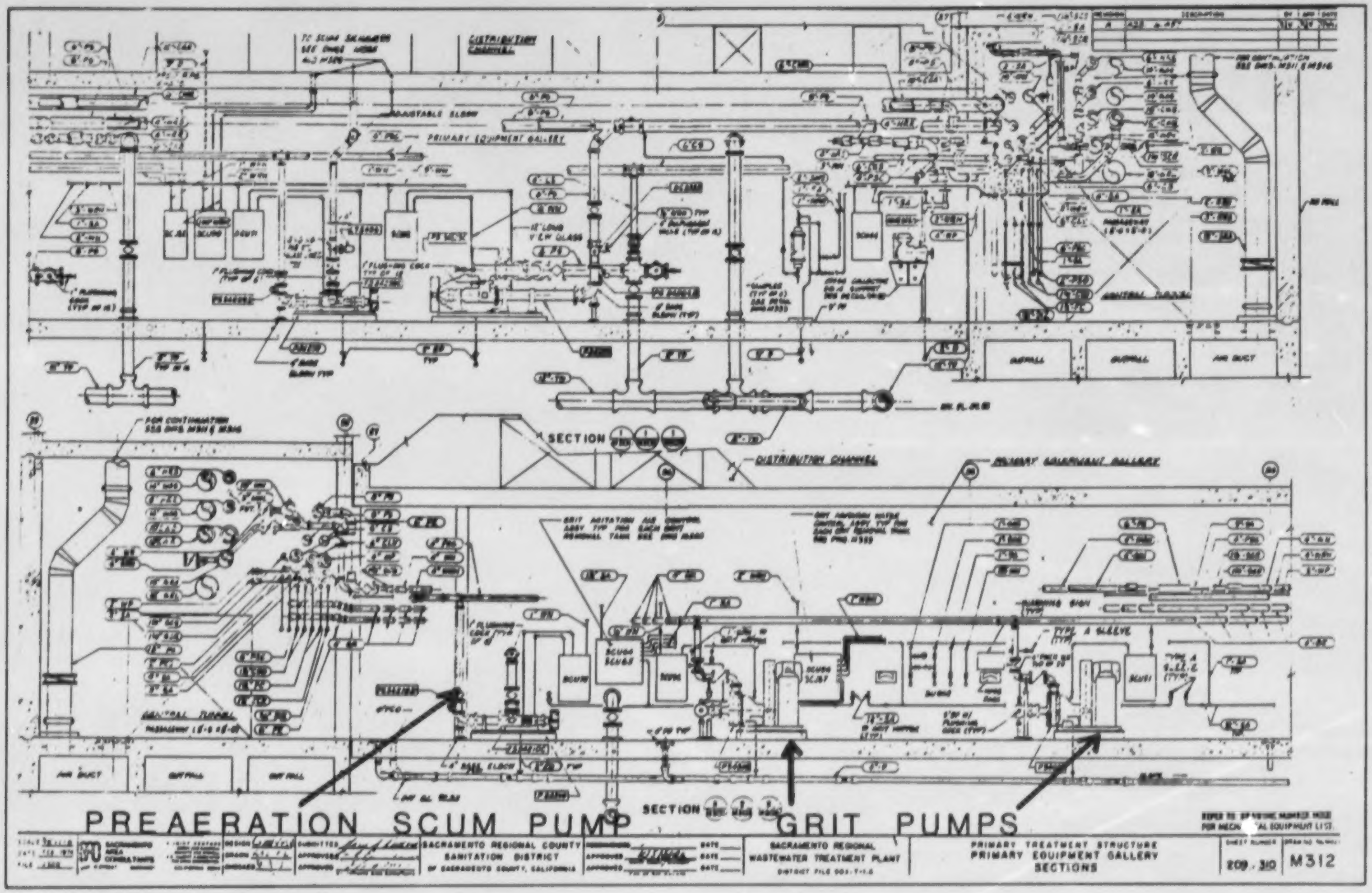
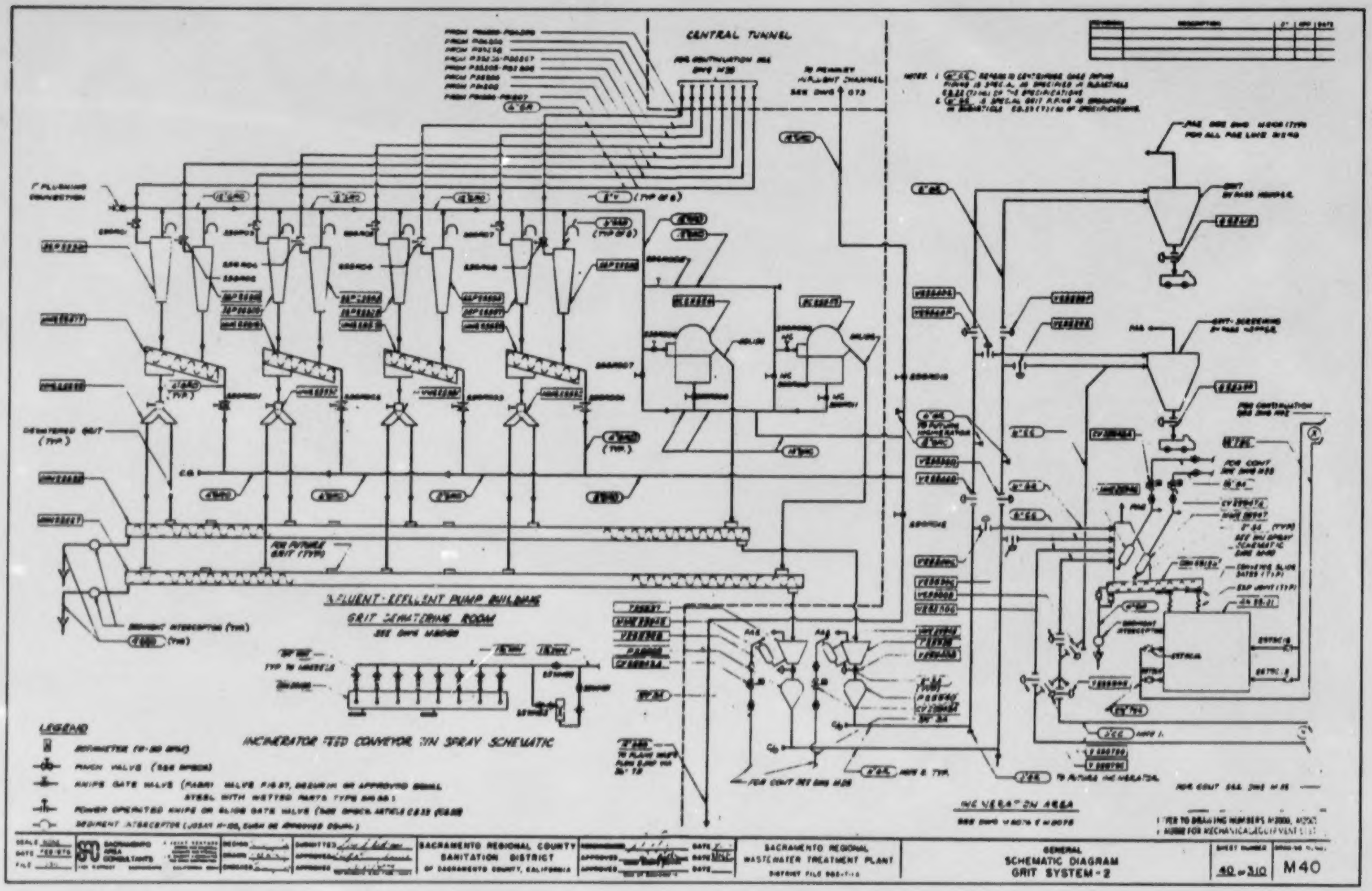

PREAERATION SCUM PUMP
GRIT PUMPS
SECTION
SECTION
DISTRIBUTION CHANNEL
PRIMARY EQUIPMENT GALLERY
CENTRAL TUNNEL
AIR DUCT
OUTFALL
OUTFALL
SACRAMENTO REGIONAL COUNTY
SANITATION DISTRICT
OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL
WASTEWATER TREATMENT PLANT
PRIMARY TREATMENT STRUCTURE
PRIMARY EQUIPMENT GALLERY
SECTIONS
209 . 310
M312

FIGURE 6.19 GRIT PUMPS LOCATED IN GALLERY BENEATH GRIT TANKS


CENTRAL TUNNEL
EFFLUENT-EFFLUENT PUMP BUILDING
GRIT DEWATERING ROOM
INCINERATOR FEED CONVEYOR WASH SPRAY SCHEMATIC
INCINERATION AREA
DEWATERED GRIT (TYP)
FOR FUTURE GRIT (TYP)
SEDIMENT INTERCEPTOR (TYP)
GRIT BYPASS HOPPER
GRIT-SCREENING BYPASS HOPPER
TO FUTURE INCINERATOR
LEGEND
PINCH VALVE
KNIFE GATE VALVE
POWER OPERATED KNIFE OR SLIDE GATE VALVE
SEDIMENT INTERCEPTOR
SACRAMENTO AREA CONSULTANTS
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
GENERAL
SCHEMATIC DIAGRAM
GRIT SYSTEM - 2
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M40

FIGURE 6.20 GRIT DEWATERING WITH CYCLONIC SEPARATORS

In combined sewer systems, the instantaneous rates of grit arriving at a treatment facility during a storm may be as much as 20 to 30 times the average amount. In addition to the ability of the equipment to handle large quantities of grit, it must be efficient in removing grit at high flow. If it is not, grit will carry over into primary settling tanks and may plug sludge withdrawal hoppers and sludge pumps. Grit can create excessive wear on pumps and packing and other downstream equipment. It may also be deposited in digestion tanks, eventually forcing the removal of a digestion tank from service.

E. Raw Wastewater Pumps

When more than one influent pump is used, the capacity to divert raw wastewater flow to any combination of pumps should be a part of the design. This will assure reliability of plant operation if one or more pumps must be taken out of service. Each pump and its channel section should be capable of being isolated from the rest of the system using slide gates. Separate drains should be provided for each isolated section. Influent pumps must have a sufficient net positive suction head. In general, this is the minimum water level at the center line of the pump impeller.

A sump ahead of the influent pumps can collect grit and other debris. By using variable speed pumps and Parshal flumes, the use of sumps can be avoided. The influent level in the flume can be used to control the throttling on the pumps. It should be noted however that in some larger plants the intermittent use of bar screens can interfere with water surface measurement in Parshall flumes. These flumes can be done away with by putting flow meter controllers on the discharge end of the variable speed pumps.

Influent pump horsepower can be saved by taking advantage of high flow conditions. If the pump controllers are located in a sump downstream from the influent sewage pipe, this control can be allowed to rise during periods of high flow. This will permit the water level in the sump to rise and reduce the head the pump has to pull against.

Influent pump controllers are critical for plant performance. Controllers should be capable of modulating severe inflow fluctuations so that flow to treatment processes is increased or decreased gradually. Uncontrolled shock flow surges can force sludge out of final clarifiers and into the effluent streams. This type of problem can be avoided by initially installing the proper controllers on the influent pumps.

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UNIT PROCESS DESIGN - PRIMARY SEDIMENTATION

UNIT 7

UNIT 7 - UNIT PROCESS DESIGN - PRIMARY SEDIMENTATION

OBJECTIVES

At the conclusion of this presentation the participant will be able to:

- Define Primary sedimentation and Class II sedimentation.
- Discuss the importance of proper sedimentation tank sizing and the pros and cons of rectangular versus circular tanks.
- Design efficient inflow and equalization channels.
- List three advantages of submerged launderers over overflow weirs.
- List the attributes of air spray scum collection.
- Design efficient scum collection systems.
- Discuss the characteristics of a good sludge collection and removal system.
- Identify three methods of controlling sludge pumping.
- Design efficient, operable sludge piping systems.

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UNIT 7 - UNIT PROCESS DESIGN - PRIMARY SEDIMENTATION

The function of primary sedimenttion is to remove settleable solids from the wastewater stream, and thereby reduce the suspended solids concentration of the sewage. This form of treatment is based on the principle that, in a liquid in a relatively quiescent state, particles with a higher specific gravity than the liquid in which they are suspended settle out. Additionally, flocculation of particles in sewage is a factor to be considered in primary sedimentation. Class II sedimentation is the type of settling that occurs when low concentrations of flocculant particles separate from a liquid. This is a characteristic of the primary sedimentation process.

There are theoretical considerations which affect the performance of flocculant settling tanks. Particle agglomeration occurs during settling which causes the settling velocity to increase. The agglomeration is a result of differential sedimentation velocities of the particles and, to a lesser extent, velocity gradients in the clarifier. The increased settling velocities caused by agglomeration mean that Class II sedimentation efficiency is a function of retention time as well as overflow rate. Because of the effect of residence time on settling velocity, the performance of primary sedimentation tanks is best predicted from laboratory settling tests. These considerations, in turn, affect the design of primary clarifiers.

A. Tank Surface Area and Geometry

The surface area of a tank is based on the overflow rate. This may be determined from laboratory data or previous experience with similar wastewaters. When the area has been determined, the depth of the clarifier may be found on the basis of the desired detention time. The length of overflow weirs is usually based on a specified weir overflow rate. For example, the Great Lakes-Upper Mississippi River Board of State Sanitary Engineers states that "weir" loadings should not exceed 10,000 gallons per linear foot per day for plants designed for average flows of one mgd or less.

Solids removal varies, depending on tank geometry. In general, rectangular tanks are provided with counter current withdrawal, while circular tanks have central withdrawal of sludge.

It is imperative that wastewater be distributed equally among all primary sedimentation tanks. The most efficient method to achieve equal distribution is by the use of flow splitter boxes with division weirs. In larger plants, this is not easily accomplished, and long distribution channels are often used. Such channels should be designed so that there is a minimum differential head loss down the channel at all flows. The inlet from the channel to each tank should be designed with a small head loss to insure that each tank receives the same amount of flow.

B. Inlet Characteristics

Inlet velocities at each primary sedimentation tank should never exceed 1.5-2.0 feet per second. This may necessitate aeration of the influent channels to keep solids in suspension. Shearfusers may be used for this purpose, and they can be recessed into channels to prevent debris accumulation. Each shearfuser should have its own air supply to keep the device clear of obstructions.

Inlet gates to each tank should be provided with target baffles, and the tanks themselves should have finger baffles to minimize short circuiting. The water level in primary settling tanks may be controlled by modulating sluice gates. The gates should be modulated to maintain preset water levels.

C. Equalization of Flow

Another method of achieving equal distribution of wastewater among primary sedimentation tanks is by use of a hydraulic control system at the effluent end of each tank. This system has been used successfully on a battery of 12 primary clarifiers at a wastewater treatment plant in Sacramento, California (see Figure 7.1). The system consists of a series of submerged launders with about 2 1/2-inches diameter orifices. They were designed to have an 18" head loss between the water surface in the sedimentation tank and the effluent channel at peak flow. The common channel, into which all tanks release the primary effluent, discharges through a control gate. At no flow, the gate is closed and the water level between the effluent channel and primary sedimentation tanks is the same. As the flow increases, the tailwater gate opens and the level in the channel drops to compensate for the head loss in the orifices. At peak flow, the gate valve is opened all the way and the level in the channel is 18" below the level in the settling tank. If one tank attempts to take more flow, the head will rise in this tank and the flow will redistribute itself among the other tanks.

D. Tank Size

The size of primary sedimentation tanks depends upon the flow requirements of the treatment facility. However, there should be sufficient hydraulic capacity among the basins to pass peak plant flow if one of the tanks is taken out of service. Detention periods for primary sedimentation range from 1-1.5 hours when secondary treatment is involved, to 1.5-2.0 hours for primary treatment only. A liquid depth of 9-10 feet is adequate for retention of settleable solids without excessive detention times.

Both rectangular and circular basins are used for primary sedimentation. Multiple rectangular tanks require less area than multiple circular tanks and for this reason are used where ground area is at a premium. Rectangular tanks lend themselves to nesting with preaeration and aeration tanks in activated sludge plants. When using rectangular tanks, it is possible to have short suction piping between the tank and sludge pumps. This

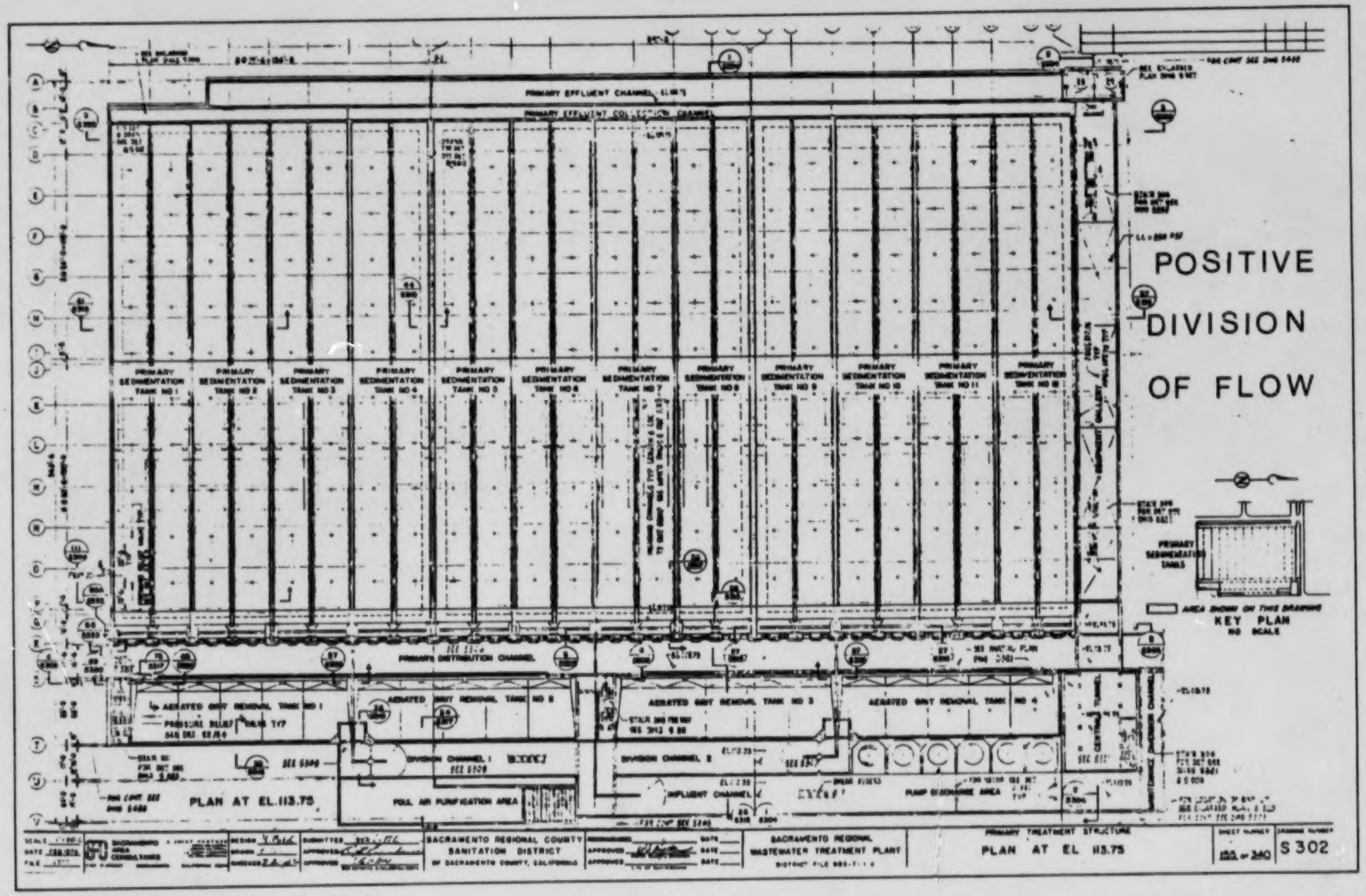
PRIMARY EFFLUENT CHANNEL
PRIMARY EFFLUENT COLLECTION CHANNEL
PRIMARY SEDIMENTATION TANK NO 1
PRIMARY SEDIMENTATION TANK NO 2
PRIMARY SEDIMENTATION TANK NO 3
PRIMARY SEDIMENTATION TANK NO 4
PRIMARY SEDIMENTATION TANK NO 5
PRIMARY SEDIMENTATION TANK NO 6
PRIMARY SEDIMENTATION TANK NO 7
PRIMARY SEDIMENTATION TANK NO 8
PRIMARY SEDIMENTATION TANK NO 9
PRIMARY SEDIMENTATION TANK NO 10
PRIMARY SEDIMENTATION TANK NO 11
PRIMARY SEDIMENTATION TANK NO 12
POSITIVE
DIVISION
OF FLOW
PRIMARY DISTRIBUTION CHANNEL
AERATED GRIT REMOVAL TANK NO 1
AERATED GRIT REMOVAL TANK NO 2
AERATED GRIT REMOVAL TANK NO 3
AERATED GRIT REMOVAL TANK NO 4
DIVISION CHANNEL 1
DIVISION CHANNEL 2
INFLUENT CHANNEL
PLAN AT EL.113.75
FOUL AIR PURIFICATION AREA
PUMP DISCHARGE AREA
PRIMARY SEDIMENTATION TANKS
AREA SHOWN ON THIS DRAWING
KEY PLAN
NO SCALE
SACRAMENTO REGIONAL COUNTY
SANITATION DISTRICT
OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL
WASTEWATER TREATMENT PLANT
PRIMARY TREATMENT STRUCTURE
PLAN AT EL 113.75
S 302

FIGURE 7.1 HYDRAULIC CONTROL OF FLOW

permits the development of maximum positive suction head and reduces the probability of the pump clogging.

E. Effluent Launders

The effluent launders should extend over a sufficient area of the sedimentation tank (25-30 percent) to minimize the effects of upward flow velocities on settled solids. Submerged launders have some advantages over the more traditionally used overflow weir. Submerged launders reduce the free fall turbulence normally present with weirs, and therefore minimize the release of odors from primary effluent. By discharging wastewater below the surface of a settling basin, submerged launders reduce floatables in the effluent. This form of effluent weir also reduces algae and slime growth accumulation along the edges of primary sedimentation tanks.

F. Scum Collection and Transfer

Scum collection from the surface of primary settling tanks is generally accomplished in one of two fashions. In circular tanks, skimmers are attached to the sludge removal mechanism. In rectangular tanks, the scum is usually collected at the effluent end of the tanks with the flights returning at the liquid surface. The scum is moved by the flights to a point where it is trapped by baffles for removal.

The scum can be moved across the surface by air or water jets to a point of collection at the head end of the tank. This minimizes the scum piping system and locates collection as far from the effluent end of the tank as possible. In many cases, air spray appears to be more effective than water. Air can use the same plumbing as waste, and can be run at 4.0 csm at 3.5 psi or 3.5 csm at 4.0 psi at a nozzle. Using air prevents clogging. Air spray must be protected from wind and may have to be augmented with water during peak flows in large plants.

Collected scum should be pumped by positive displacement pumps to the scum processing tanks. It is desirable for scum piping to be manifold, so that flexibility of separate scum disposal is possible. For example, scum may be pumped to either digesters or scum thickeners. Glass-lined pipe should be used for all scum piping to minimize grease buildup.

G. Sludge Collection

Sludge is collected in rectangular tanks using a pair of endless conveyor chains to which are attached, at intervals, flights extending the full width of the tank. These longitudinal flights convey sludge to cross collectors located at the inlet end of a tank. Here other sludge conveyors, either flights or screws, move the sludge to hoppers. The sludge collector should remain submerged over the entire length of travel. This will prolong the life of the flights since they will not be exposed to alternate periods of wetting and drying. Although redwood is the most commonly used flight material, Douglas fir lasts just as long and it is a stronger wood. Collectors should be equipped with manual adjustable variable speed drives for the optimum speed setting. The operator should have flexibility to run the sludge collection system either continuously or intermittently.

Recently, non-metallic chains have been developed for use in sludge conveyor systems. There are certain features of this type of chain that may make it an attractive alternative to metal chains. Since non-metallic chain weighs about one-fourth as much as metallic chains, the former is much easier to handle. In a four-year study conducted at a wastewater treatment plant in Minnesota, both types of chain were compared on identical primary clarifiers (Nedinsky and Quandt, 1980). The molded links of ten-foot sections of the non-metallic chain were joined together with snap lock pins. This saved time and manpower over assembly of metallic chains. Weight differences between the two chains permitted the non-metallic form to be more easily strung across flights.

Over the four-year test period, non-metallic chains performed as well as metal and there were no problems similar to those with metal chains. Additionally, there was less maintenance required on the flight wear shoes when non-metallic chains were used. It was necessary, however, to place weights on the redwood flights to keep them from floating out of the basin. It took about twice as long to remove the metal chain from the tank, since the chain had to be cut with torches and then winched out of the tank.

H. Sludge Removal

Sludge should be removed from hoppers by positive displacement pumps equipped with variable speed drives. If progressive cavity pumps are used, maximum speed should be below 300 rpm. Longer life and less maintenance can be attained on this type of pump by adding one more stage than is required for design. This will reduce wear in the pump by lowering back-pressures within the cavities. It is important, on positive displacement pumps, to measure pressure at the discharge end. If pressure here is allowed to build up when the pump is operating (e.g., due to clogging down the line), the pump may be destroyed. Therefore, the gauge must be capable of shutting down the pump when pressure becomes excessive.

The pumping system should be designed so that one pump is directly connected to each sludge hopper (see Figure 7.2). It is undesirable to use a single pump for more than one hopper, since it would not be possible to control flow from each hopper simultaneously.

There are three methods by which sludge pumping can be controlled. Sludge blanket level can be used to initiate pumping with shutdown occurring when sludge density reaches a preset level, or sludge pumping can be continuous, with speed modulation based on the sludge blanket level. Finally, a timer can be used to shut the pumps down (see Figure 7.3). It is advisable to have at least two of these options available to the operator for maximum flexibility.

A sight glass in the sludge suction lines will assist operators in determining the condition of the primary sludge and may be used for flow verification. Sight glasses should be located on the suction end of pumps due to the high pressures that can build up on the discharge side. Both sludge

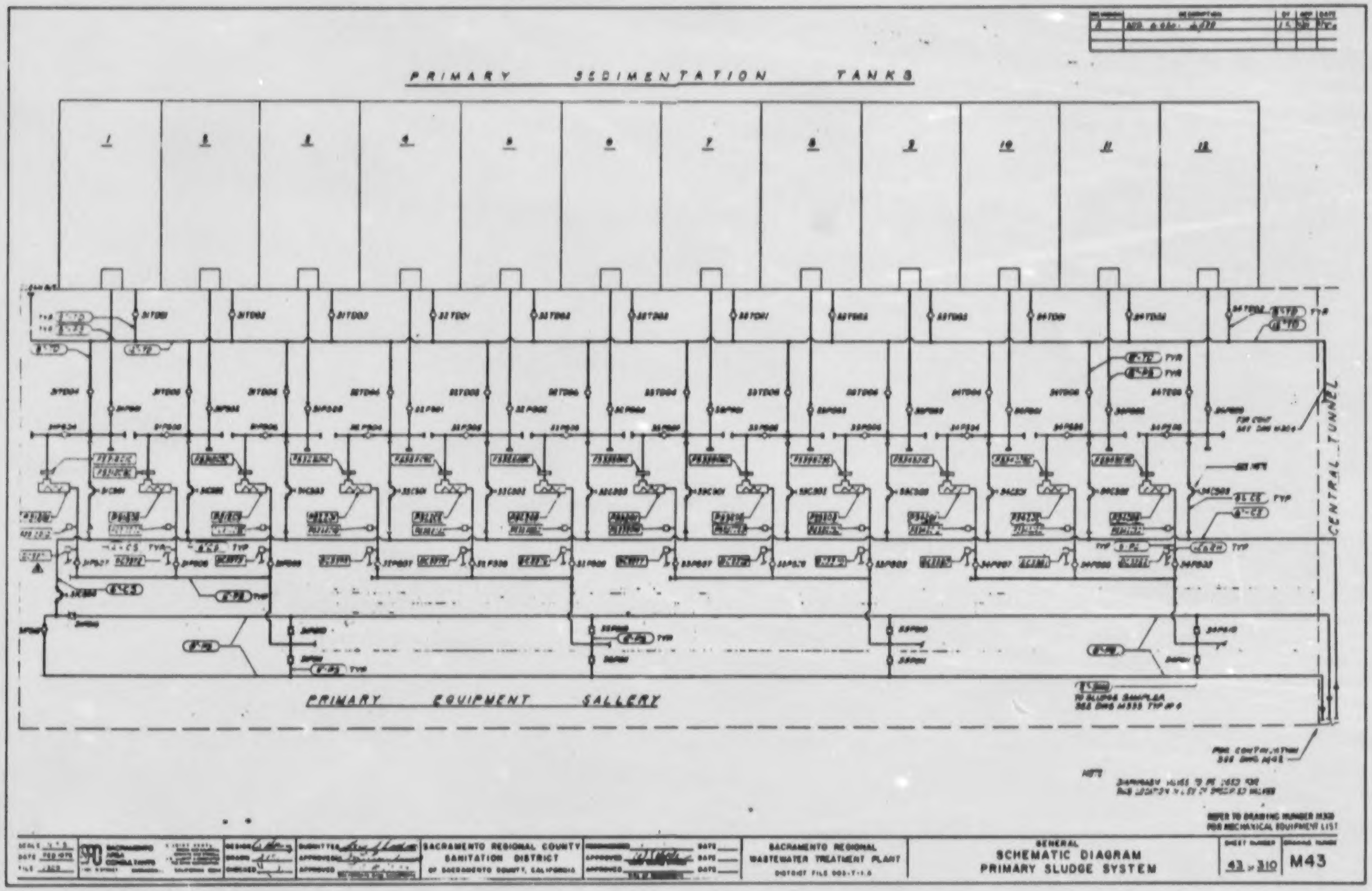
PRIMARY SEDIMENTATION TANKS
1
2
3
4
5
6
7
8
9
10
11
12
CENTRAL TUNNEL
PRIMARY EQUIPMENT GALLERY
TYP
REFER TO DRAWING NUMBER M30 FOR MECHANICAL EQUIPMENT LIST
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
GENERAL
SCHEMATIC DIAGRAM
PRIMARY SLUDGE SYSTEM
43 OF 310
M43

FIGURE 7.2 ONE PUMP PROVIDED FOR EACH SLUDGE HOPPER

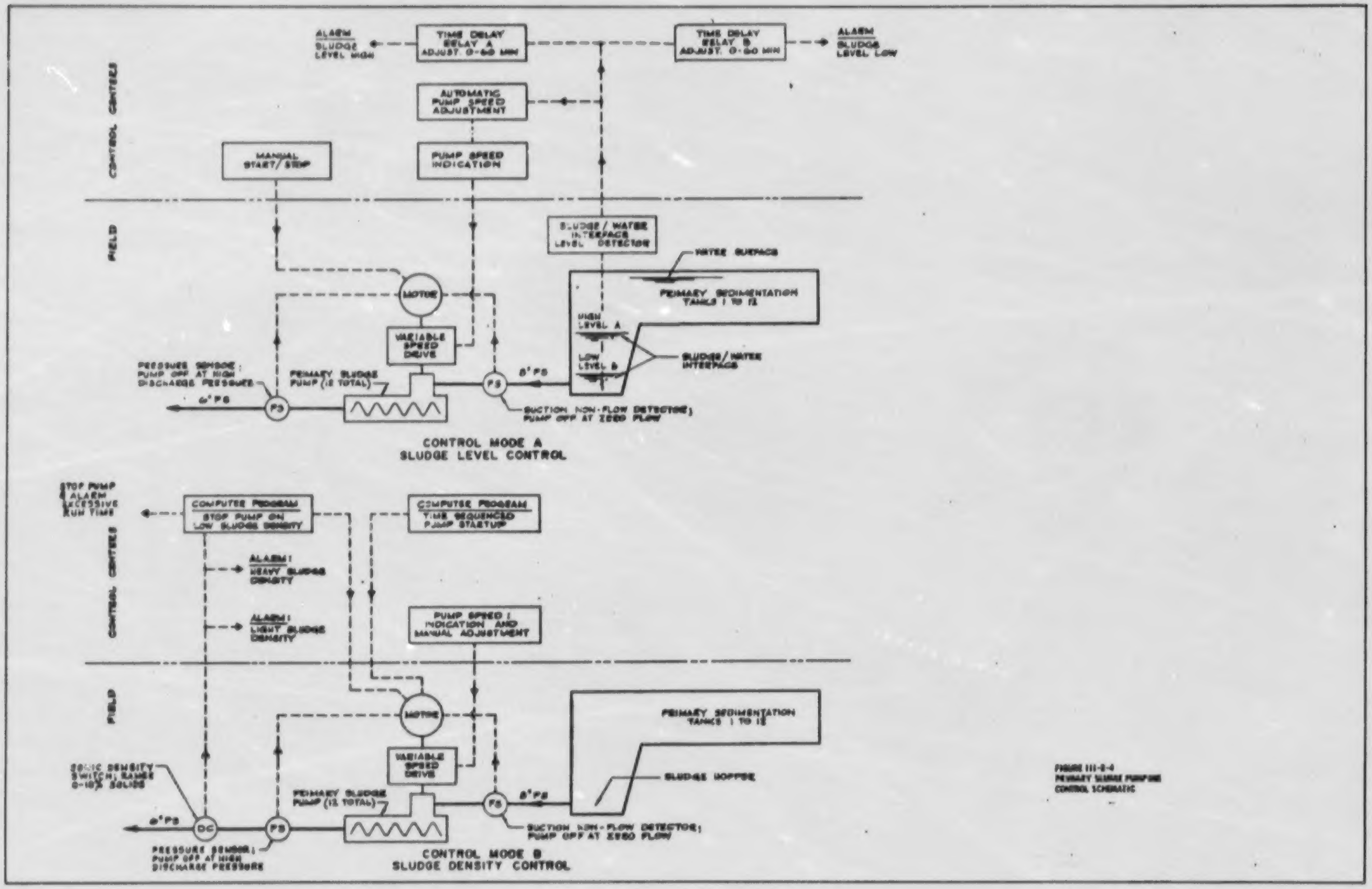
ALARM
SLUDGE LEVEL HIGH
TIME DELAY RELAY A ADJUST. 0-60 MIN
TIME DELAY RELAY B ADJUST. 0-60 MIN
ALARM
SLUDGE LEVEL LOW
CONTROL CENTERS
AUTOMATIC PUMP SPEED ADJUSTMENT
MANUAL START/STOP
PUMP SPEED INDICATION
FIELD
SLUDGE / WATER INTERFACE LEVEL DETECTOR
WATER SURFACE
MOTOR
PRIMARY SEDIMENTATION TANKS 1 TO 12
HIGH LEVEL A
LOW LEVEL B
SLUDGE/WATER INTERFACE
VARIABLE SPEED DRIVE
PRESSURE SENSOR: PUMP OFF AT HIGH DISCHARGE PRESSURE
PRIMARY SLUDGE PUMP (12 TOTAL)
8" PS
6" PS
PS
FS
SUCTION NON-FLOW DETECTOR; PUMP OFF AT ZERO FLOW
CONTROL MODE A
SLUDGE LEVEL CONTROL
STOP PUMP & ALARM EXCESSIVE RUN TIME
COMPUTER PROGRAM
STOP PUMP ON LOW SLUDGE DENSITY
COMPUTER PROGRAM
TIME SEQUENCED PUMP STARTUP
ALARM: HEAVY SLUDGE DENSITY
ALARM: LIGHT SLUDGE DENSITY
PUMP SPEED: INDICATION AND MANUAL ADJUSTMENT
CONTROL CENTERS
FIELD
MOTOR
PRIMARY SEDIMENTATION TANKS 1 TO 12
VARIABLE SPEED DRIVE
SONIC DENSITY SWITCH; RANGE 0-10% SOLIDS
SLUDGE HOPPER
PRIMARY SLUDGE PUMP (12 TOTAL)
8" PS
6" PS
DC
PS
FS
SUCTION NON-FLOW DETECTOR; PUMP OFF AT ZERO FLOW
PRESSURE SENSOR; PUMP OFF AT HIGH DISCHARGE PRESSURE
CONTROL MODE B
SLUDGE DENSITY CONTROL
FIGURE III-8-4
PRIMARY SLUDGE PUMPING
CONTROL SCHEMATIC

FIGURE 7.3 AUTOMATED CONTROL OF SLUDGE PUMPING

flow and density should be measured and recorded to provide solids balance information.

Sludge piping should also be designed for flexibility and reliability (see Figure 7.4). Two glass-lined pipes should be provided to transport sludge and each pump should be connected to both lines. High sludge velocities in transfer piping (4-6 fps) are desirable to reduce buildup in the piping and to achieve high heat transfer rates in sludge heaters. Sludge from anaerobic digesters must be kept circulating through the primary sludge lines. This prevents grease accumulation in the lines and helps blend the sludges. Providing heat exchangers for raw sludge and recirculated sludge decreases buildup of heat in transport piping. The piping must be insulated if heated.

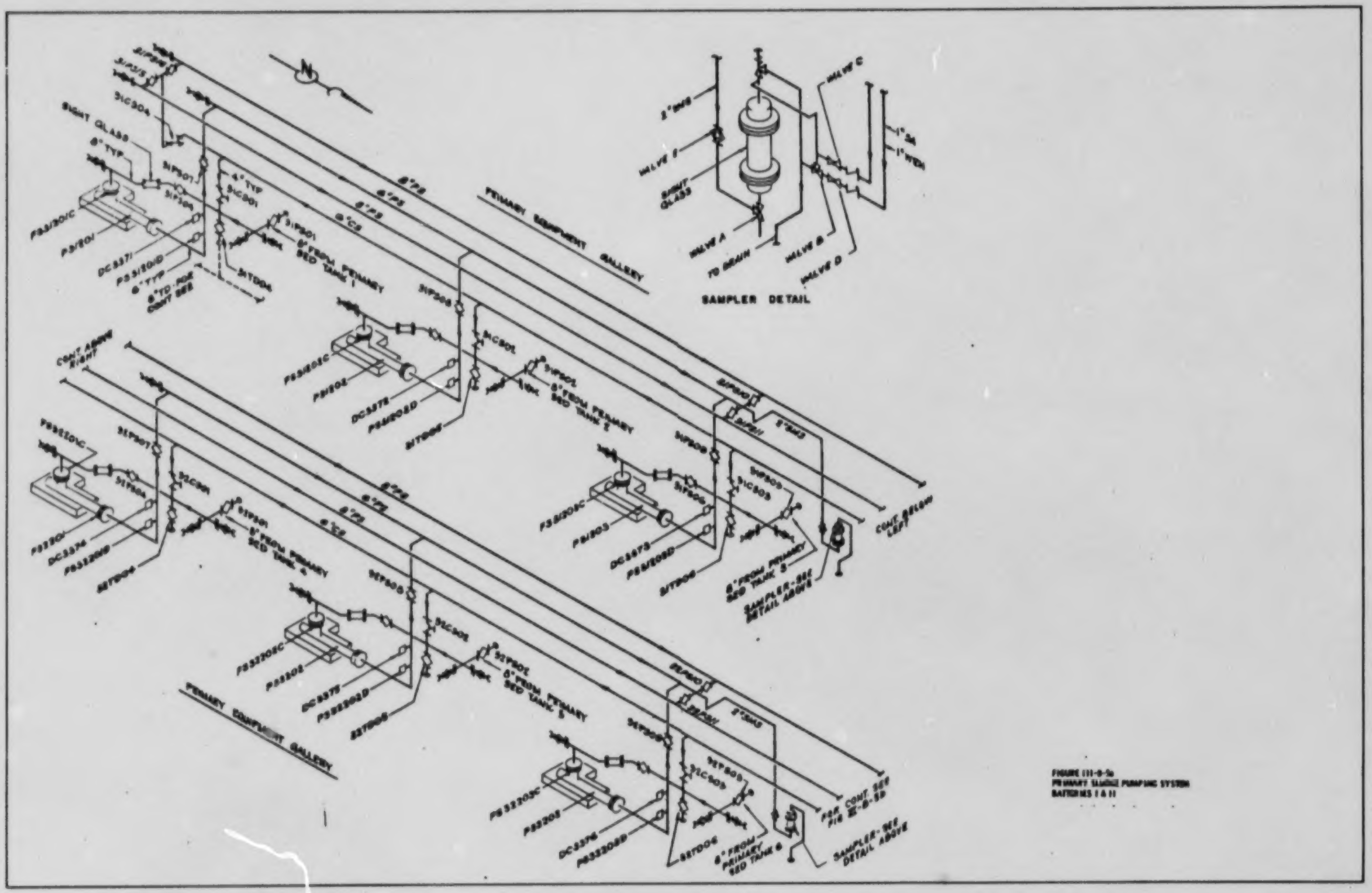
PRIMARY EQUIPMENT GALLERY
SIGHT GLASS
8" FROM PRIMARY SED TANK 1
8" FROM PRIMARY SED TANK 2
8" FROM PRIMARY SED TANK 3
8" FROM PRIMARY SED TANK 4
8" FROM PRIMARY SED TANK 5
8" FROM PRIMARY SED TANK 6
CONT ABOVE RIGHT
CONT BELOW LEFT
SAMPLER-SEE DETAIL ABOVE
PRIMARY EQUIPMENT GALLERY
VALVE A
VALVE B
VALVE C
VALVE D
VALVE E
SIGHT GLASS
TO DRAIN
1" WTR
SAMPLER DETAIL
FIGURE III-8-5a
PRIMARY SLUDGE PUMPING SYSTEM
BATTERIES I & II

FIGURE 7.4 BUILT IN SLUDGE HANDLING FLEXIBILITY

UNIT PROCESS DESIGN - AERATION BASINS

UNIT 8

UNIT 8 - UNIT PROCESS DESIGN - AERATION BASINS

OBJECTIVES

At the conclusion of this presentation, the attendee should be able to:

- Identify the goals of a designer in providing an activated sludge unit process.
- Write the formula for maintenance of a constant food to microorganism ratio, and explain its significance.
- Describe the relationship of growth rate of microorganism to solids retention time.
- Describe the relationship of food to microorganism ratio to solids retention time.
- Write an explanation of Henry's Law including an identification of its importance to the Design Engineer.
- Discuss oxygen transfer and the effects of bubble size in transfer efficiency.
- List four differing types of activated sludge treatment and describe each.
- Discuss the option and design characteristics for an activated sludge facility.
- List at least four "design hints" dealing with influent channels.
- Discuss techniques to provide flexibility in activated sludge systems.
- Look up six elements which should be metered in any activated sludge system.
- Discuss the criticality of aeration and list three "design hints" which facilitate operation and maintenance.
- Describe foam control techniques.
- List four elements which should be included in a facility to assist in maintenance and repair.

UNIT 8 - UNIT PROCESS DESIGN - AERATION BASINS

All biological unit processes employ bacteria to oxidize organic materials in wastewater using the following biochemical reaction:

--- Organics + O_2 + bacteria + nutrients → new bacteria + H_2O + CO_2. ---

The goal of wastewater treatment is to minimize the organics in the effluent stream. This is done by insuring that the organics in the feed are the rate-limiting reactant.

The effluent substrate concentration is dependent upon the rate of microbial growth. The goal of treatment plant operation is to control the growth rate of the microorganisms to produce the desired effluent quality. The goal of the designer, on the other hand, is to provide the operator with the flexibility needed to maintain the desired organism growth rate despite wide variations in influent flow rate and quality.

A. Methods to Maintain Activated Sludge

One means of maintaining the desired growth rate is to maintain a constant food-to-microoganism ratio (F:M). This parameter is defined as:

$$U = \frac{\Delta s/\Delta t}{x_t}$$

Where:

U = Food-to-microorganism ratio
$\Delta s/\Delta t$ = Mass of substrate utilized per unit of time
x_t = Mass of organisms in the system

A disadvantage of this approach is that there is no convenient way of determining the mass of organisms in the system. Generally, this number is approximated by using the volatile suspended solids in the system.

The growth rate can be controlled by manipulating the biological solids retention time (SRT). This parameter is defined as:

$$\Theta_c = \frac{x_t}{(\Delta x/\Delta t)}$$

Where:

θ_c = Solids retention time
$\Delta x/\Delta t$ = Mass of solids lost per unit time by intentional and unintentional wastage

The solids retention time approach is easier to implement because it does not require the determination of the number of organisms in the system.

The food-to-microorganism ratio can be related to the solids retention time by the following expression:

$$\frac{1}{\theta_c} = Y\,(u) - K_d$$

Where:

Y = Microbial yield coefficient
K_d = Microbial decay coefficient

B. Gas Transfer-Oxygen Flow

A factor to be considered in the design of activated sludge and any biological treatment process is the rate of gas transfer, primarily oxygen, into the liquid phase. The solubility of oxygen is governed by Henry's Law, which states that the saturation concentration of oxygen in water is proportional to its partial pressure in the gas phase. For purposes of rate calculations, oxygen transfer is generally assumed to occur across a laminar boundary layer. Based on this assumption, molecular transport principles can be applied and the rate of oxygen transfer given by:

$$N = K_{La}\,(C_s - C)$$

Where:

N = Rate of oxygen transfer
K_{La} = Mass transfer coefficient
C = Actual concentration of oxygen in the bulk liquid
C_s = Saturation concentration of oxygen in liquid

The rate of oxygen transfer is affected by a number of factors. The solubility of oxygen in the liquid affects the driving force and thus directly influences the rate of transfer. Oxygen solubility is a function of temperature, partial pressure and salinity of the solution. Therefore, these parameters all indirectly affect the rate of oxygen transfer.

For a given oxygen flow rate, smaller-sized bubbles will provide a larger transfer area and thus a higher mass transfer rate. Bubble size is in turn affected by various system parameters. At high air flow rates, bubbles will tend to coalesce. The properties of the suspending medium, particularly the surface tension and the presence of a solid phase, will influence bubble size. Finally, the type of aeration equipment can determine bubble size in a basin.

The effects of liquid-phase properties on mass transfer are commonly taken into account by using a factor which is the ratio of K_{La} in wastewater to K_{La} in pure water.

C. Types of Activated Sludge Treatment

Activated sludge is one of the most commonly used biological processes for the treatment of domestic and industrial wastewaters. The activated sludge process has been classified on the basis of mixing regimen (e.g., plug-flow vs. contact stabilization), microbial growth rate (e.g., conventional vs. extended aeration) and source of oxygen (e.g., air vs. pure oxygen). Within these classifications, there are a number of process modifications which merit closer examination.

The completely-mixed process is characterized by a uniform concentration of substrate and microbial solids throughout the basin. Since the concentration of organic substrate is low relative to the mass of microorganisms, this process resists shock loads of soluble organics. Complete mixing dilutes low-level toxic shocks to sublethal levels. Kinetically, this system is at a disadvantage because biochemical oxidation takes place at a rate governed by the effluent concentration.

Plug-flow treatment is characterized by a decreasing substrate concentration and oxygen demand throughout the length of the tank. Pure-oxygen systems utilize this flow plan by providing several reactors in series. One modification of this approach is tapered aeration. In tapered aeration, the air supply is decreased near the outlet end of the tank in the same manner that the oxygen supply is regulated in pure oxygen systems. One advantage of tapered aeration is its ability to resist bleed-through of substrate during shock loads.

Extended aeration is a modification of the activated sludge process which forces the microbial population to respire endogenously. This necessitates a relatively low organic loading and long aeration time. For these reasons, it is generally applicable only in small treatment plants. The long solids retention time reduces sludge production, making the process applicable to package plants that receive minimal maintenance.

The contact stabilization process utilizes the ability of microorganisms to rapidly take up and store substrate. A 20 to 40 minute contact time of the activated sludge with the incoming wastewater is provided. This is followed by solids/liquid separation after which the sludge is reaerated in a separate basin while the microorganisms oxidize the stored organics. The process reduces the aeration volume requirements compared to that needed in conventional activated sludge. However, the process requires careful attention to insure that synthesis or washout does not occur in the contact tank and that the organics are oxidized completely during reaeration.

Step aeration is a process modification in which the feed is introduced at a number of points along the length of the aeration basin. This spreads the oxygen demand throughout the length of the basin. The primary advantage of this process is the flexibility which permits several modes of operation ranging from plug flow to contact stabilization. Step aeration has also been shown to produce a better settling sludge for a given loading rate. Another advantage is the ability to reduce temporarily the solids loading to the clarifier during settling upsets.

D. Optimal Design

An optimal design is based on pilot studies which select the solids retention time or food-to-microorganism ratio determined by performance, oxygen consumption, solids production and settling data. Once the F:M or SRT has been established, the mixed liquor suspended solids level, detention time and desired range of recycle rates can be computed from design equations. In the absence of pilot data, equipment can be sized by assuming an SRT or F:M. When SRT or F:M is assumed, it is necessary to estimate the solids production and oxygen requirements based on experience with similar wastewaters.

E. Operational Considerations

As in primary sedimentation, it is important that influent to the aeration basins be equally distributed among all tanks in use. The techniques discussed for primary settling tanks are applicable for activated sludge aeration basins. In general, providing equal head loss to each reactor and keeping velocities low will assure equal distribution of the wastewater. Care must be taken to prevent solids deposition. This can be done by providing air agitation in the influent channels.

The channels should be designed so that as expansion of treatment capacity takes place, equal distribution of wastewater among additional aeration basins will continue. Provisions should be made for by-passing the primary settling tanks and discharging raw wastewater directly to the reactors following pretreatment. Simple manual adjustments should be included to insure operational flexibility.

Inlets and outlets for each aeration basin should have valves, gates, stop plates, weirs or other devices to permit flow control to any unit and to maintain a constant liquid level. If any unit is taken out of service, the hydraulic properties of the system should permit the maximum instantaneous hydraulic load to be carried by the remaining units.

F. Designing for Flexibility

Maximum flexibility can be designed into the aeration basin system influent channels. Liquid surfaces should be free from obstructions so that foam and scum can pass through the channel system.

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Maximum flexibility can be designed into the aeration basin system by enabling the operator to run the basins in different modes (i.e., plug flow, step aeration or contact stabilization) (see Figure 8.1). This is especially helpful in temperate zones where temperature fluctuations can make periodic changes in the process used desirable. To accomplish this, it is necessary to design influent channels capable of feeding the basins at several locations.

Pure oxygen plants are run in the same fashion as aerated plants. This implies that oxygen plants should have the same flexibility (see Figure 8.2). This is especially true when the plant is subjected to seasonal loading. Additionally, there should be multiple oxygen compressors if step aeration capabilities will be included (see Figure 8.3).

Multiple aeration basins provide the flexibility to treat the minimal flows encountered when a plant is first put on line and still provide sufficient treatment capacity when design flows are achieved. The dimensions of each tank should be adequate to maintain effective mixing and utilization of air. Liquid depths should range from 10 to 20 feet. Flow velocities in all areas of the tanks should be high enough to prevent solids deposition. Fillets should be provided around the aeration tanks where wall and bottom meet. Basins should have freeboards of not less than 18 inches. Tanks with mechanical aerators require a minimum of 3 to 5 feet of freeboard.

G. Metering and Sampling

Proper metering and sampling of all aspects of the secondary treatment process are required if the operator is to maintain control of the system. The areas to be metered include:

(1) Return activated sludge (RAS) to each aerator,
(2) Sludge withdrawal rate from each clarifier,
(3) Waste activated sludge from the clarifier,
(4) Influent flow to each aeration basin,
(5) Mixed liquor suspended solids, and
(6) Air discharge in each aeration basin. (Air flow rate indicators for each pass are desirable.)

It is recommended that RAS be discharged above the aeration tank water level to allow visual inspection of the sludge loading.

H. Aeration of Activated Sludge

Aeration in the activated sludge process is critical as it provides both the oxygen required for microbial respiration and the turbulence necessary to mix influent wastewater with the MLSS. Spacing of diffusers should be in accordance with oxygen requirements throughout the length of a tank. Diffusers should be designed to facilitate adjustments of their spacing without major revisions to air header piping. Arrangements of the diffusers should permit their removal for inspection, maintenance and replacement without dewatering the tank and without shutting off the air supply to other diffusers in the tank. Be certain to provide adequate mixing throughout the

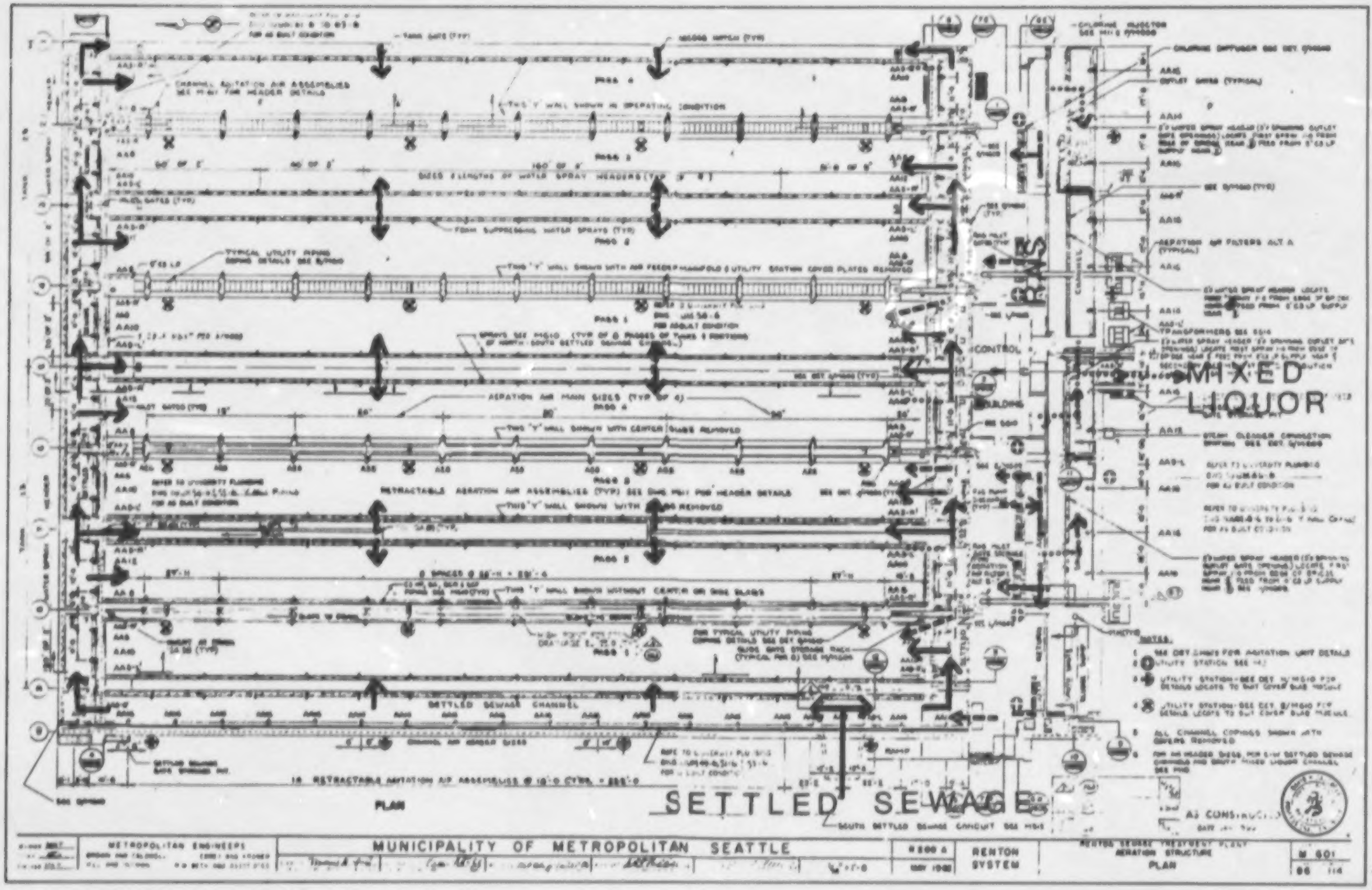

MIXED
LIQUOR
SETTLED SEWAGE
RAS
CONTROL
BUILDING
SETTLED SEWAGE CHANNEL
PLAN
AS CONSTRUCTED
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
RENTON SYSTEM
RENTON SEWAGE TREATMENT PLANT
AERATION STRUCTURE
PLAN
M 601

FIGURE 8.1 FLEXIBILITY IN MODE OF OPERATION

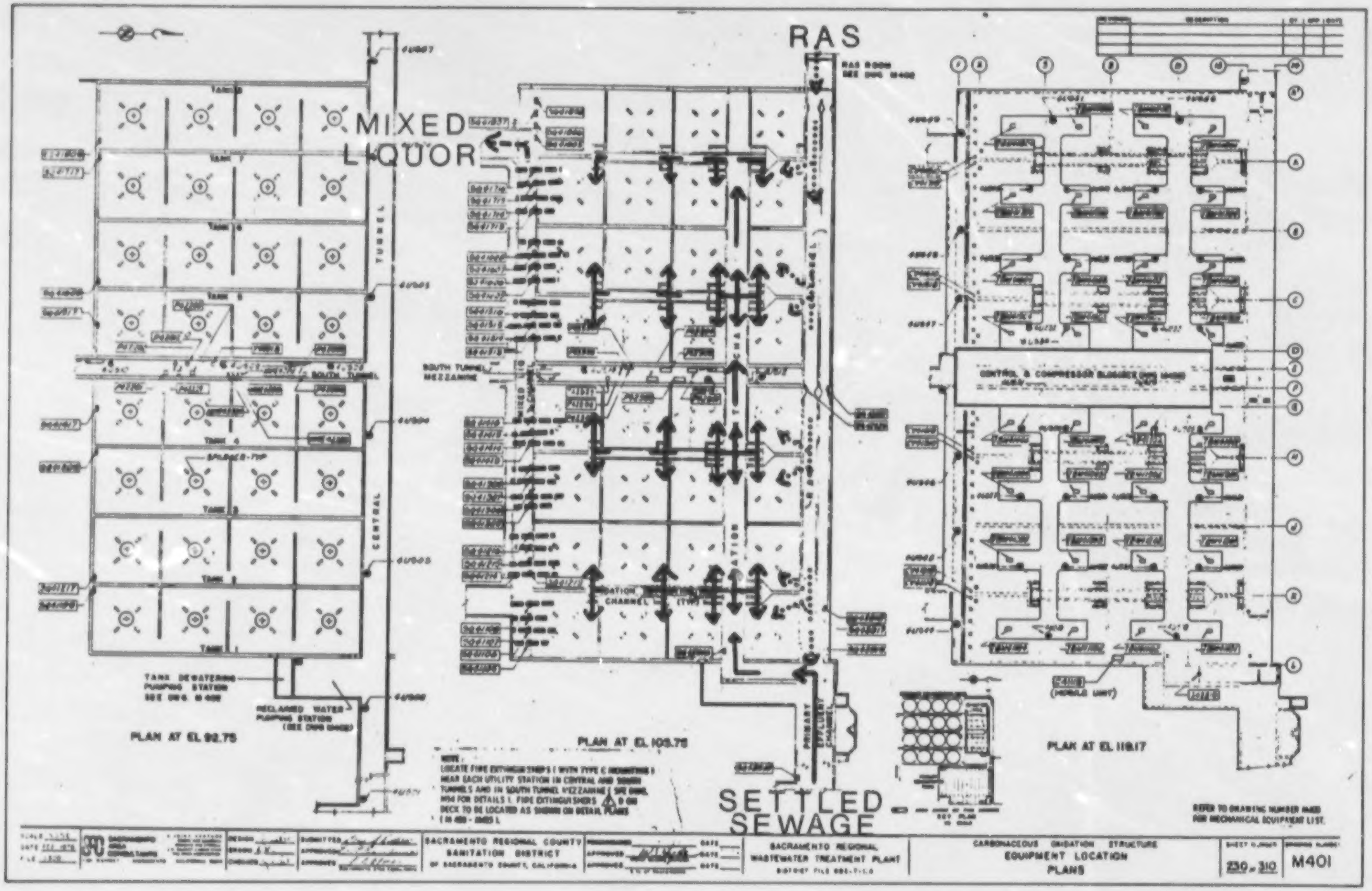

RAS
MIXED LIQUOR
SETTLED SEWAGE
RAS ROOM SEE DWG M402
TANK 1
TANK 2
TANK 3
TANK 4
TANK 5
TANK 6
TANK 7
TANK 8
SOUTH TUNNEL
CENTRAL TUNNEL
SOUTH TUNNEL MEZZANINE
SPARGER-TYP
TANK DEWATERING PUMPING STATION SEE DWG M409
RECLAIMED WATER PUMPING STATION (SEE DWG M405)
PLAN AT EL 92.75
PLAN AT EL 105.75
PLAN AT EL 119.17
AERATION CHANNEL (TYP)
PRIMARY EFFLUENT CHANNEL
CONTROL & COMPRESSOR BUILDING
(MOBILE UNIT)
NOTE: LOCATE FIRE EXTINGUISHERS 1 WITH TYPE C MOUNTING 1 NEAR EACH UTILITY STATION IN CENTRAL AND SOUTH TUNNELS AND IN SOUTH TUNNEL MEZZANINE (SEE DWG. M04 FOR DETAILS). FIRE EXTINGUISHERS ON DECK TO BE LOCATED AS SHOWN ON DETAIL PLANS
REFER TO DRAWING NUMBER M400 FOR MECHANICAL EQUIPMENT LIST.
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
CARBONACEOUS OXIDATION STRUCTURE
EQUIPMENT LOCATION
PLANS
230 of 310
M401

FIGURE 8.2 FLEXIBILITY IN MODE OF OPERATION IN OXYGEN PLANT

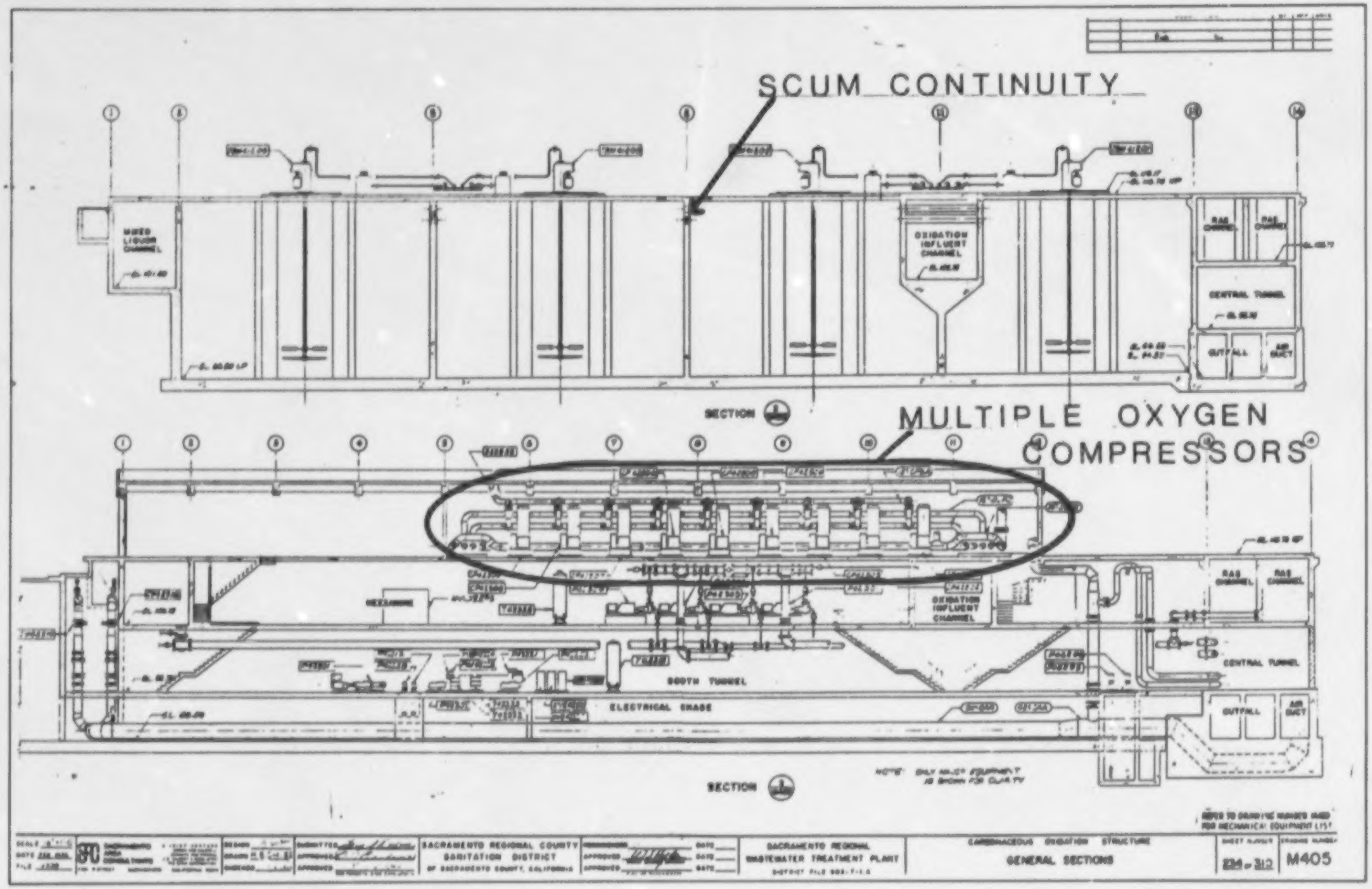

SCUM CONTINUITY
MULTIPLE OXYGEN COMPRESSORS
MIXED LIQUOR CHANNEL
OXIDATION INFLUENT CHANNEL
RAS CHANNEL
CENTRAL TUNNEL
OUTFALL
AIR DUCT
SECTION
SOUTH TUNNEL
ELECTRICAL CHASE
NOTE: ONLY MAJOR EQUIPMENT IS SHOWN FOR CLARITY
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
CARBONACEOUS OXIDATION STRUCTURE
GENERAL SECTIONS
M405

FIGURE 8.3 MULTIPLE OXYGEN COMPRESSORS FOR STEP AERATION

total practical range of aeration intensity. Avoid diffuser placement patterns that can create unmixed cores or dead spots.

Provide adequate air compressor capacity, including standby capacity for maintenance and repair under maximum uptake requirements. There must be sufficient intake air filtering for the selected dissolution equipment (e.g., use a bag filter for fine bubble diffusers). In cold climates, the specified capacity of the motor drive should take into acount that the temperature of ambient intake air may be well below zero. This may require oversizing of the motor or a means of reducing the rate of air delivery to prevent overheating or damage to the motor.

Air flow into aeration basins can be controlled by a dissolved oxygen (DO) feedback mechanism. Probes measuring DO in the basin should have feedback to open or close an air control valve depending on the amount of DO in the MLSS. This alters the pressure on the main distribution system, increasing or decreasing the throttling on the blowers. This is an energy efficient control system and can refine process control. Air control facilities should be provided that permit the operator to vary aeration intensity to match the loading, sludge quality and process status requirements.

I. Foam Control on Aeration Basin

Provide foam and scum control on the basins such as water spray systems. The capability to introduce chlorine into the tanks will provide flexibility to deal with Nircardia foam should it develop. In closed reactors (e.g., pure oxygen), it is advisable to provide both foam control and removal systems. Extra foam sprayers on pure oxygen reactors will insure that foam does not get into the oxygen return system (see Figure 8.4). Scum production on aeration basins may occur as a result of a rapid decline in organic loading to a plant (e.g., during weekends or holidays when industrial discharge may be zero or very low). This is due to a rapid decline in the food-to-microorganism ratio followed by death of a large number of microorganisms in the aeration basin. The organisms will float to the surface of the basin and form a scum. If the decline in loading can be anticipated, then extra sludge can be wasted and the F:M ratio will not drop low enough to cause massive microbial death.

J. Maintenance and Repair

Positive allowances should be made for reactor maintenance and repair. Protect against the loss of solids with isolation gates, intermediate drains and the ability to pump channel contents into operating aeration basins. Be sure to provide sufficient tank bottom slope to assure complete drainage (see Figures 8.5, 8.6 and 8.7).

Adequate washdown water supplies should be provided along with steam cleaning and compressed air. Utility power outlets capable of 120/220/440 volt delivery are helpful.

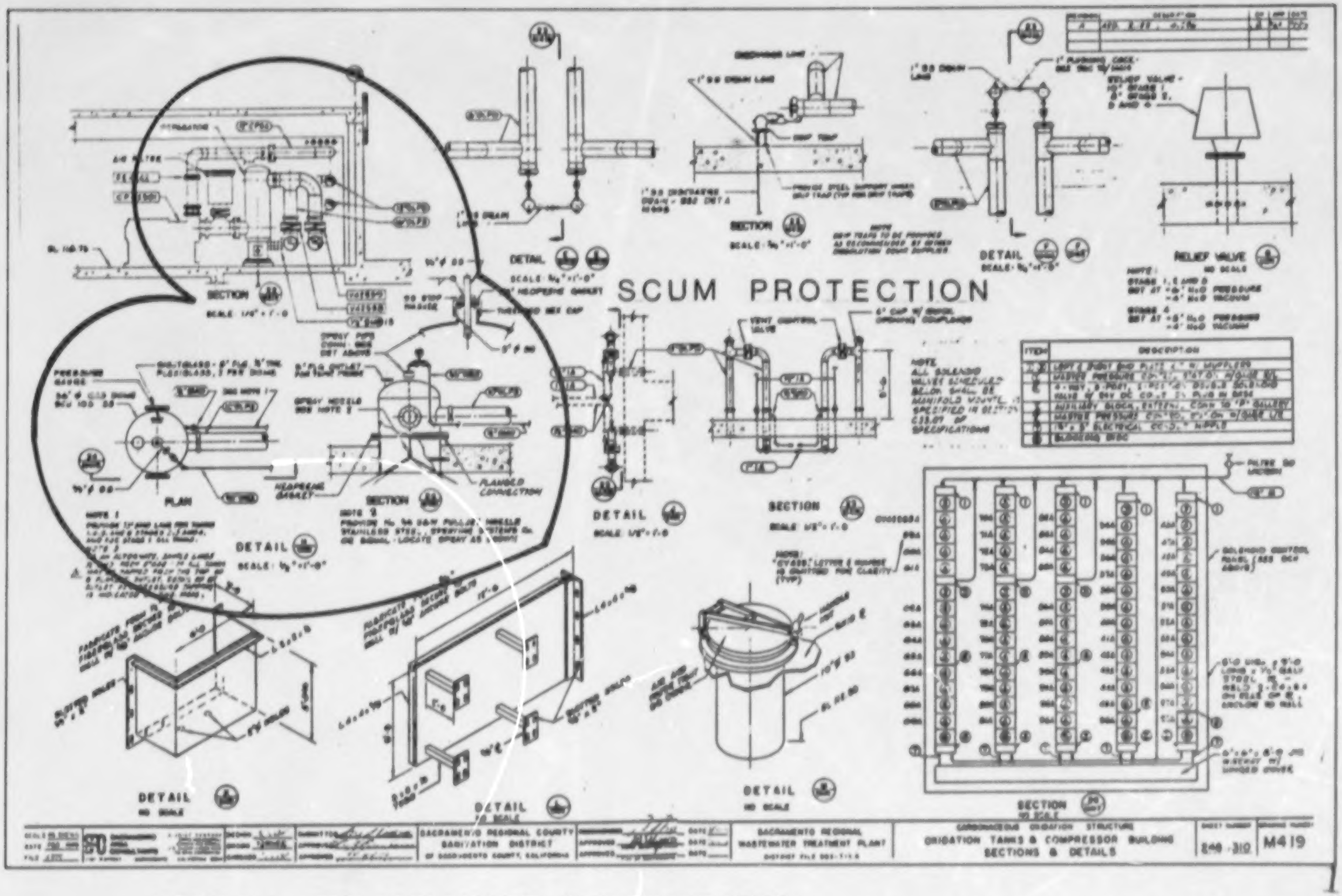

SCUM PROTECTION
SECTION
DETAIL
PLAN
RELIEF VALVE
NO SCALE
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
OXIDATION TANKS & COMPRESSOR BUILDING
SECTIONS & DETAILS
248-310
M419

FIGURE 8.4 EXTRA FOAM SPRAYERS IN OXYGEN REACTORS

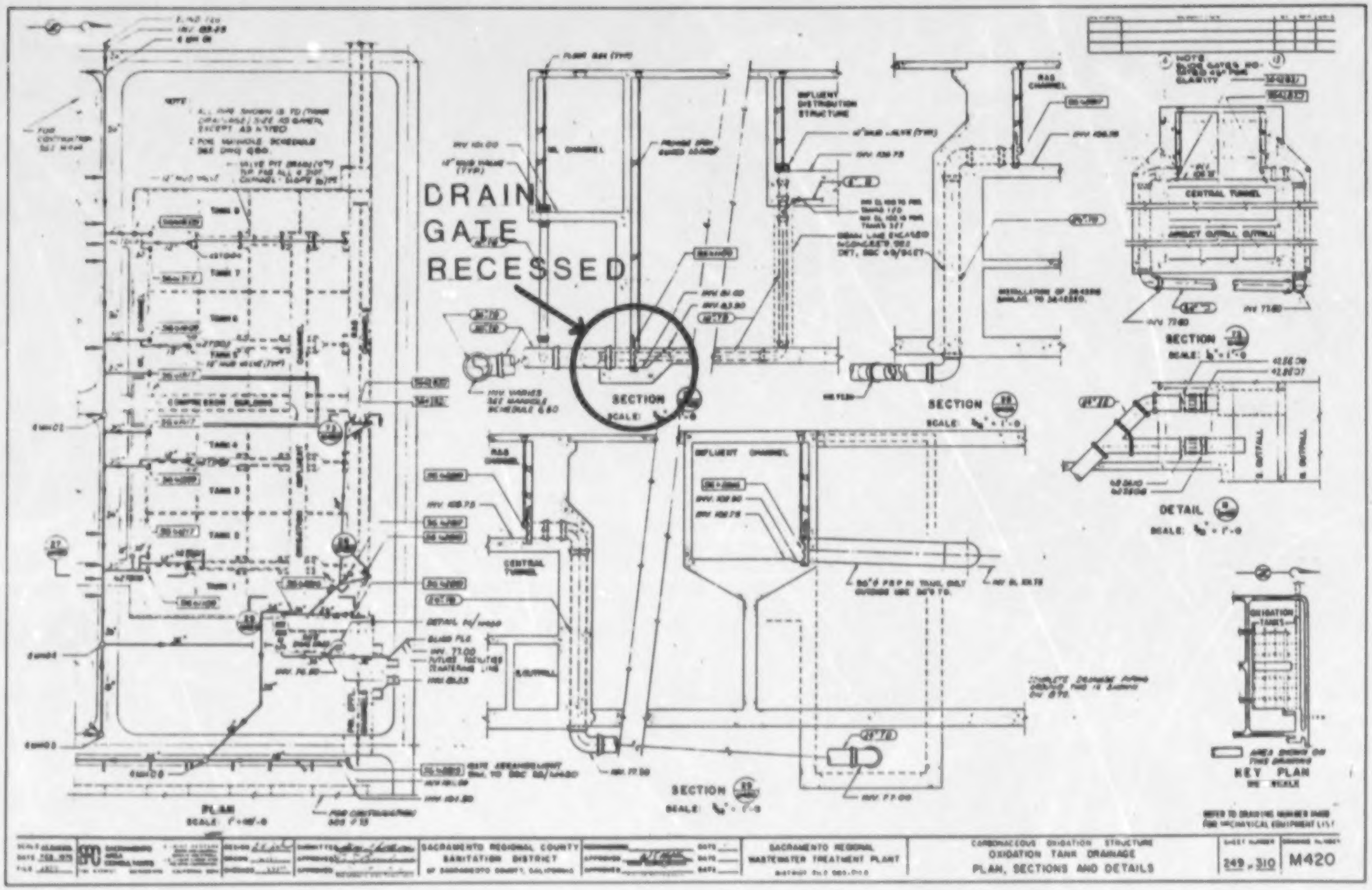

DRAIN
GATE
RECESSED
SECTION
SECTION
SECTION
SECTION
DETAIL
PLAN
KEY PLAN
CENTRAL TUNNEL
COMPRESSOR BUILDING
INFLUENT DISTRIBUTION STRUCTURE
INFLUENT CHANNEL
RAS CHANNEL
CENTRAL TUNNEL
TANK 8
TANK 7
TANK 6
TANK 5
TANK 4
TANK 3
TANK 2
TANK 1
SACRAMENTO REGIONAL COUNTY
SANITATION DISTRICT
SACRAMENTO REGIONAL
WASTEWATER TREATMENT PLANT
CARBONACEOUS OXIDATION STRUCTURE
OXIDATION TANK DRAINAGE
PLAN, SECTIONS AND DETAILS
249 of 310
M420

FIGURE 8.5 RECESSED DRAIN GATES

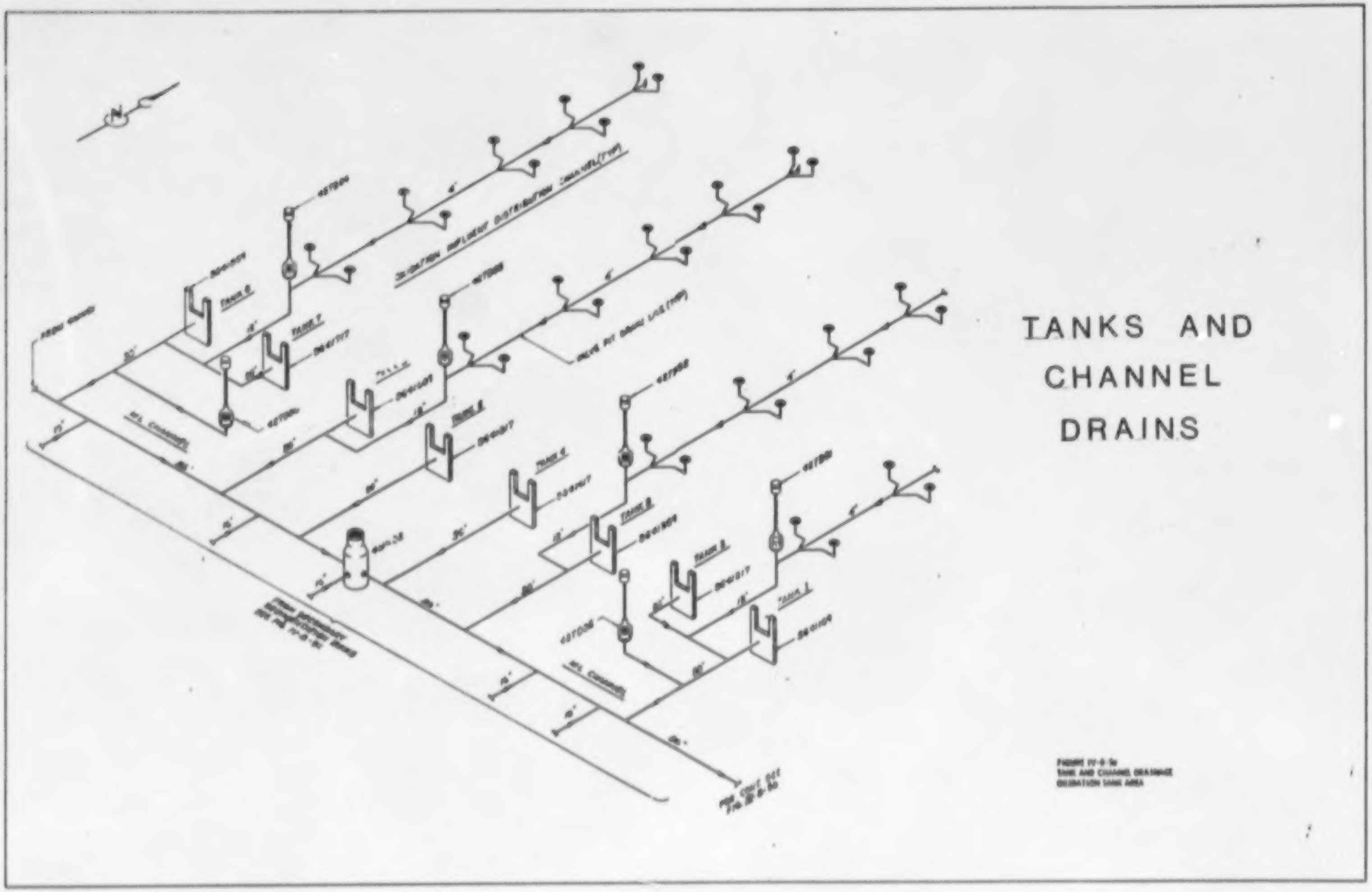

TANKS AND
CHANNEL
DRAINS

FIGURE 8.6 DRAINAGE SYSTEM

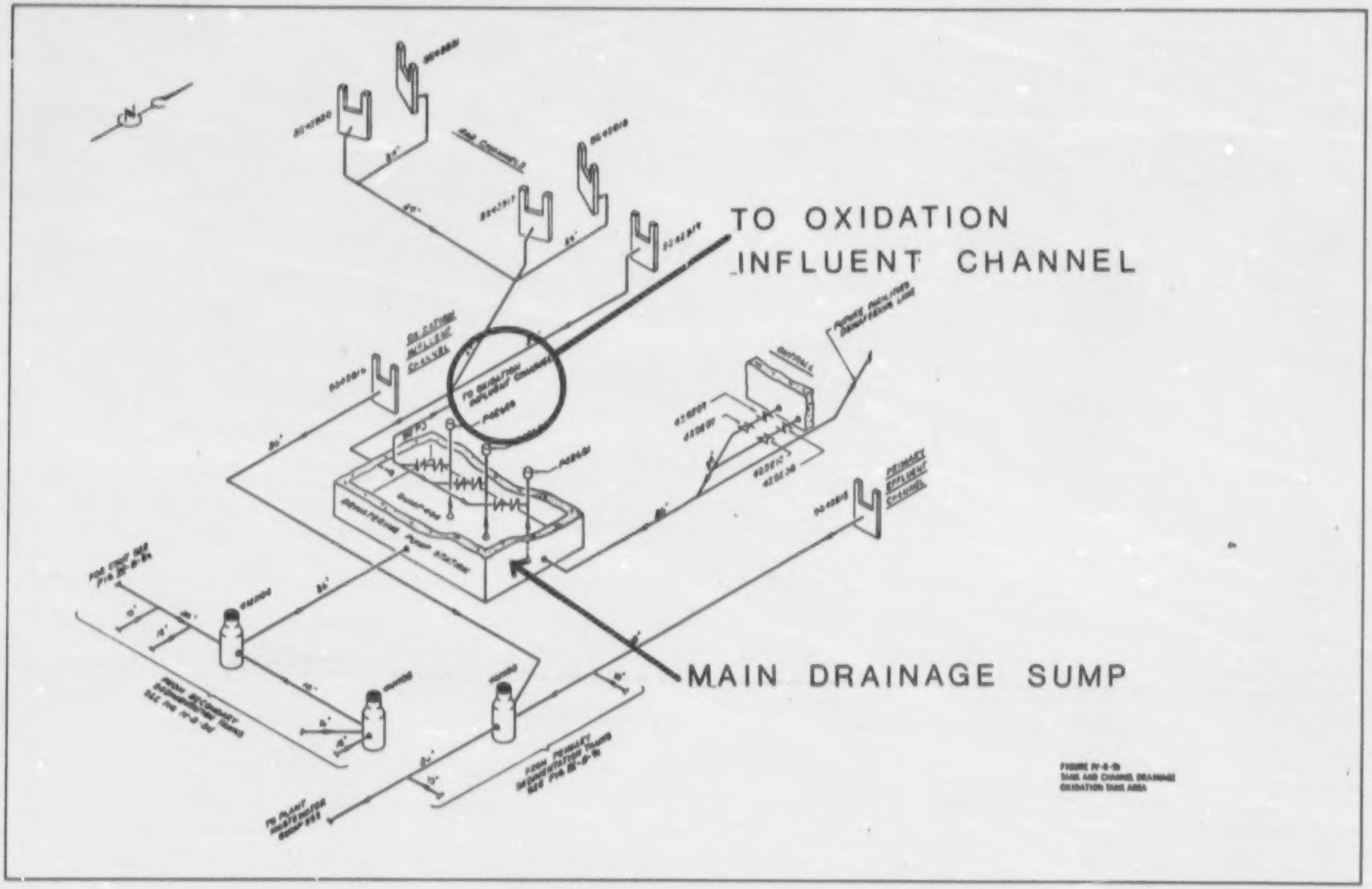

TO OXIDATION INFLUENT CHANNEL
MAIN DRAINAGE SUMP

FIGURE 8.7 OXYGEN SEPARATION AT MAIN DRAINAGE SUMP

UNIT PROCESS DESIGN - SECONDARY SEDIMENTATION

UNIT 9

UNIT 9 - UNIT PROCESS DESIGN - SECONDARY SEDIMENTATION

OBJECTIVES

At the conclusion of this presentation the attendee should be able to:

- Define the function of secondary sedimentation.
- Identify the pros and cons of various tank geometries.
- State the proper overflow rates for sedimentation tanks.
- Demonstrate an understanding of clarifier design requirements.
- Design efficient influent channels.
- State the importance of sample collection and identify acceptable techniques.
- Design scum handling equipment which is proper and efficient.
- Identify at least five "design hints" for overflow weirs.
- Design sludge collection and return systems which meet requirements and are relatively easy to operate.
- Describe adequate sludge control techniques and systems.
- List at least five elements which make maintenance and repair easier.

UNIT 9 - UNIT PROCESS DESIGN - SECONDARY SEDIMENTATION

Secondary sedimentation is a critical step in the activated sludge treatment process. The function of secondary sedimentation is to separate the activated sludge solids from the mixed liquor discharged from the aeration basin. In this capacity, sedimentation insures a final effluent that is low in BOD and suspended solids. Therefore, it is imperative that design of this process be sufficient to handle peak hydraulic loads. The design should be flexible enough for the operator to modify aspects of the process for any unique treatment situation that may be encountered.

A. Tank Geometry

Activated sludge settling tanks may be either circular or rectangular. Each of the shapes has advantages that should be considered by the Design Engineer. Using circular tanks, it is easier to achieve a good distribution of incoming flow and maintain low horizontal velocities across the tank. Circular tanks provide for the most rapid removal of solids. However, sludge pumps can be positioned closer to the sludge discharge point using rectangular clarifiers, reducing the potential for sludge line clogging by maintaining a maximum positive suction head on the pump. Rectangular clarifiers require less area than circular tanks and may be considered at sites where space is limiting. Rectangular tanks can take advantage of common wall construction for the expansion of settling facilities.

Most wastewater treatment plants are designed to operate at relatively high MLSS concentrations. Since thick sludges settle more slowly than thin sludges, it is recommended that tanks be designed for relatively low overflow rates. An average rate of 500 to 550 gpm is desirable. However, if the sedimentation tank is designed for peak hydraulic flow (1200 to 1500 gpm), flow will automatically be reduced to the 500 to 550 gpm range during average flows.

B. Clarifier Design

For larger treatment plants, a sufficient number of clarifiers must be provided to assure the meeting of hydraulic loading and effluent quality requirements when one tank is removed from service (see Figure 9.1). Each clarifier should be deep enough for separation and concentration of the sludge to occur. Generally, depths of 14 to 20 feet are recommended. After optimum design requirements are determined, at least two feet should be added to the depth to assure sufficient area for consolidation of the sludge.

The design of influent channels to all sedimentation tanks should insure an equal distribution of flows and solids. It is necessary to create a maximum head loss at each tank inlet in order to achieve this distribution

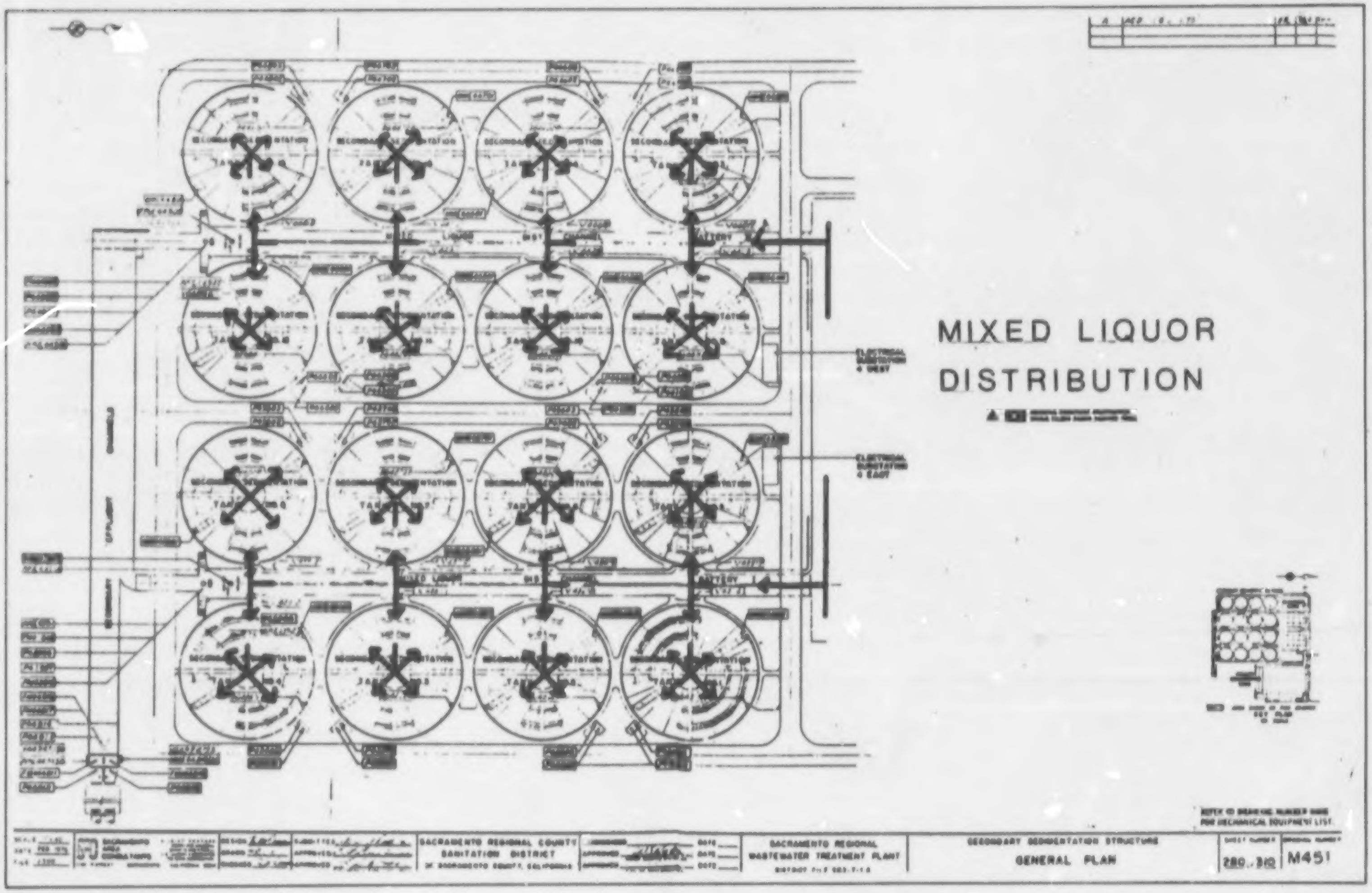

MIXED LIQUOR
DISTRIBUTION
SECONDARY SEDIMENTATION TANK
ELECTRICAL SUBSTATION 4 WEST
ELECTRICAL SUBSTATION 4 EAST
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
SECONDARY SEDIMENTATION STRUCTURE
GENERAL PLAN
280-310
M451

FIGURE 9.1 CLARIFIER REDUNDANCY FOR FLEXIBILITY

(see Figure 9.2). Velocity currents from incoming wastewater can scour settled solids from the bottom of sedimentation tanks. This can be avoided by distributing flow into tanks through multiple chambers that reduce the magnitude of the velocity currents. In center feed tanks, the diameter of the stilling chamber should be 25 to 30 percent of the overall tank diameter and should extend no more than three feet below the surface to avoid scouring deposited sludge from the sludge drawoff sump (see Figure 9.3).

C. Sample Collection

The design must provide for convenient collection of representative samples for control testing and laboratory analysis. Automatic, proportioning, refrigerated sample collectors are recommended.

Flow meters should be provided to measure and permit control of the mixed liquor into and the return sludge flow out of each clarifier. A sampling station for the clarifier effluent should also be provided to permit evaluation of the activated sludge system.

D. Scum Handling

Scum collection is mandated on all federally funded projects and is important for a good quality final effluent. Influent collection of scum should be provided in the influent distribution chambers. Skimmers are the most common method of removing scum from the tank surface (see Figure 9.4). Scum pumping to digesters should be done using positive displacement pumps. If scum is pumped to collection sumps or thickeners, centrifugal pumps may be used. All scum piping should be glass lined to reduce grease accumulation.

E. Overflow Weirs

Overflow weirs should be arranged to minimize upflow velocities and the associated turbulence. On circular clarifiers of 50 to 100 feet in diameter, weirs should be located about 1/4 to 1/3 of the radius in from the wall. For tanks larger than 100 feet in diameter, two concentric weirs should be designed. On rim feed tanks, overflow weirs should be near the center of the tank (see Figure 9.5). For rectangular clarifiers, outlet and overflow weirs should be located across at least 1/3 of the total tank surface to minimize flow velocities. In general, the designer should strive to keep upflow velocities to a minimum and keep the weir loading per foot of length as low as possible (see Figures 9.6 and 9.7).

F. Sludge Collection and Return

Sludge collection from a secondary sedimentation tank is best accomplished using hydraulic collectors (see Figure 9.8). The specific gravity of biological sludges is too low to push along with flights. In hydraulic collection systems, the driving force is the static head between the liquid surface in the sedimentation tank and that in the feed well. Because this head is fairly small, the collector pipes should remain along the tank bottom. If they are brought up (e.g., for observation), the head may be too little at low flow periods to pick up the sludge. This will necessitate a

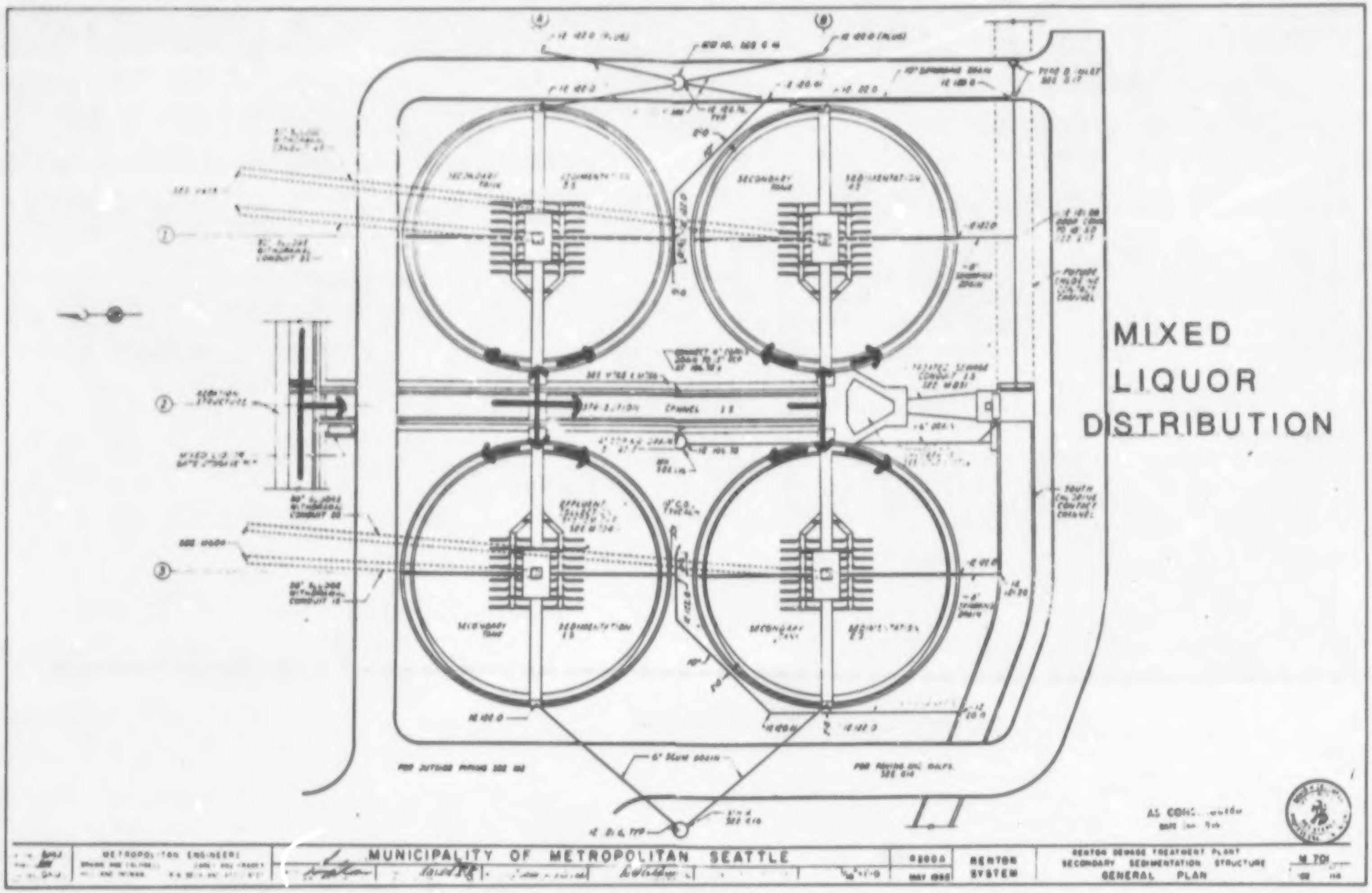

MIXED
LIQUOR
DISTRIBUTION
SECONDARY TANK
SEDIMENTATION
DISTRIBUTION CHANNEL
AERATION STRUCTURE
MUNICIPALITY OF METROPOLITAN SEATTLE
METROPOLITAN ENGINEERS
RENTON SYSTEM
RENTON SEWAGE TREATMENT PLANT
SECONDARY SEDIMENTATION STRUCTURE
GENERAL PLAN
AS CONSTRUCTED

FIGURE 9.2 HEAD LOSS AT EACH TANK INLET

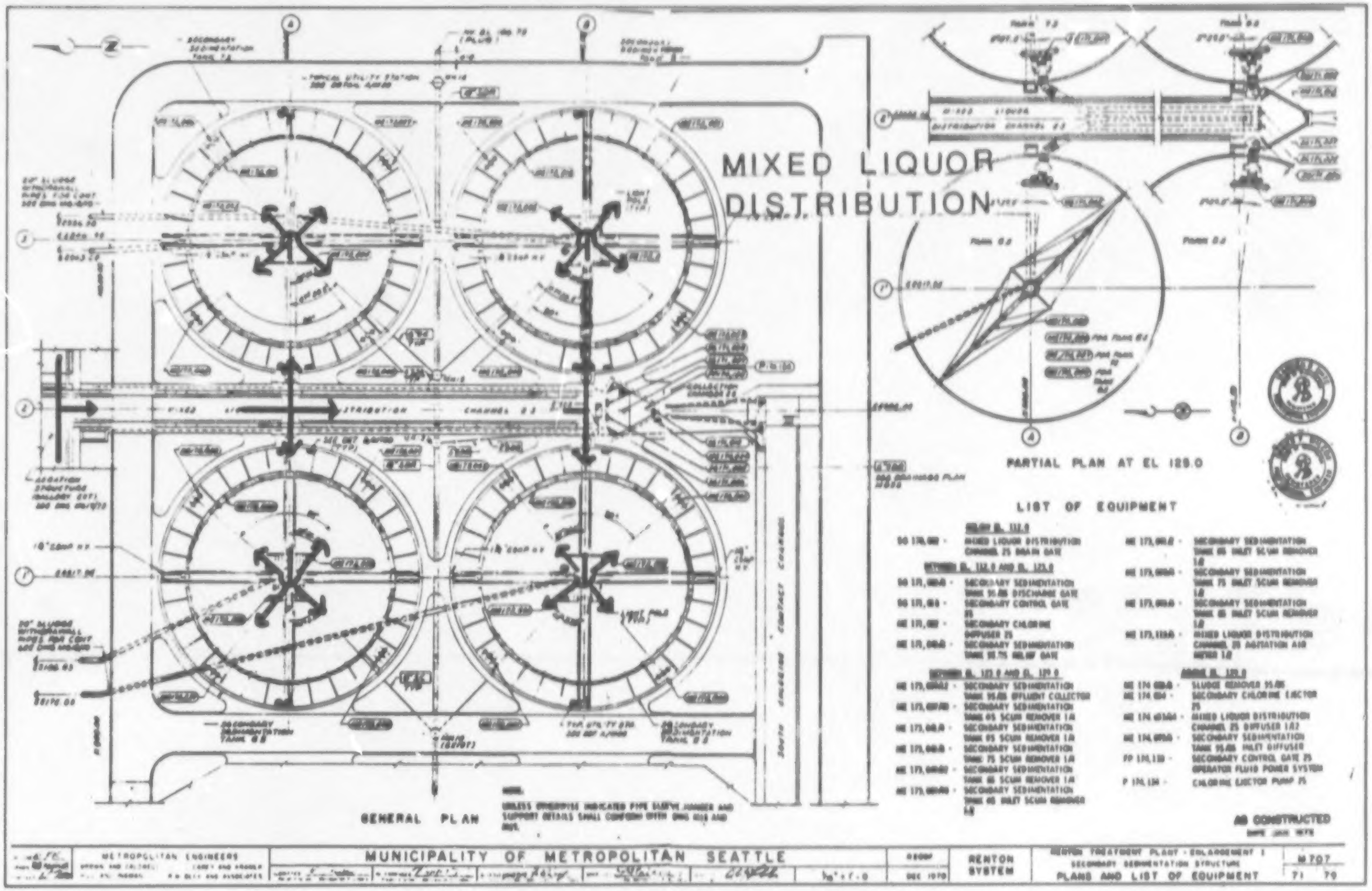

MIXED LIQUOR DISTRIBUTION
MIXED LIQUOR DISTRIBUTION CHANNEL 25
SECONDARY SEDIMENTATION TANK 7A
SECONDARY SEDIMENTATION TANK 6B
SOUTH CHLORINE CONTACT CHANNEL
GENERAL PLAN
PARTIAL PLAN AT EL 125.0
LIST OF EQUIPMENT
SECONDARY SEDIMENTATION TANK 95 SCUM REMOVER 1A
SECONDARY CONTROL GATE 25
SECONDARY CHLORINE DIFFUSER 25
SLUDGE REMOVER 95/85
SECONDARY CHLORINE EJECTOR 25
SECONDARY SEDIMENTATION TANK 95/85 INLET DIFFUSER
SECONDARY CONTROL GATE 25 OPERATOR FLUID POWER SYSTEM
CHLORINE EJECTOR PUMP 25
AS CONSTRUCTED
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
DEC 1970
RENTON SYSTEM
RENTON TREATMENT PLANT - ENLARGEMENT 1
SECONDARY SEDIMENTATION STRUCTURE
PLANS AND LIST OF EQUIPMENT
M707
71
79

FIGURE 9.3 STILLING CHAMBER AROUND CENTER FEED

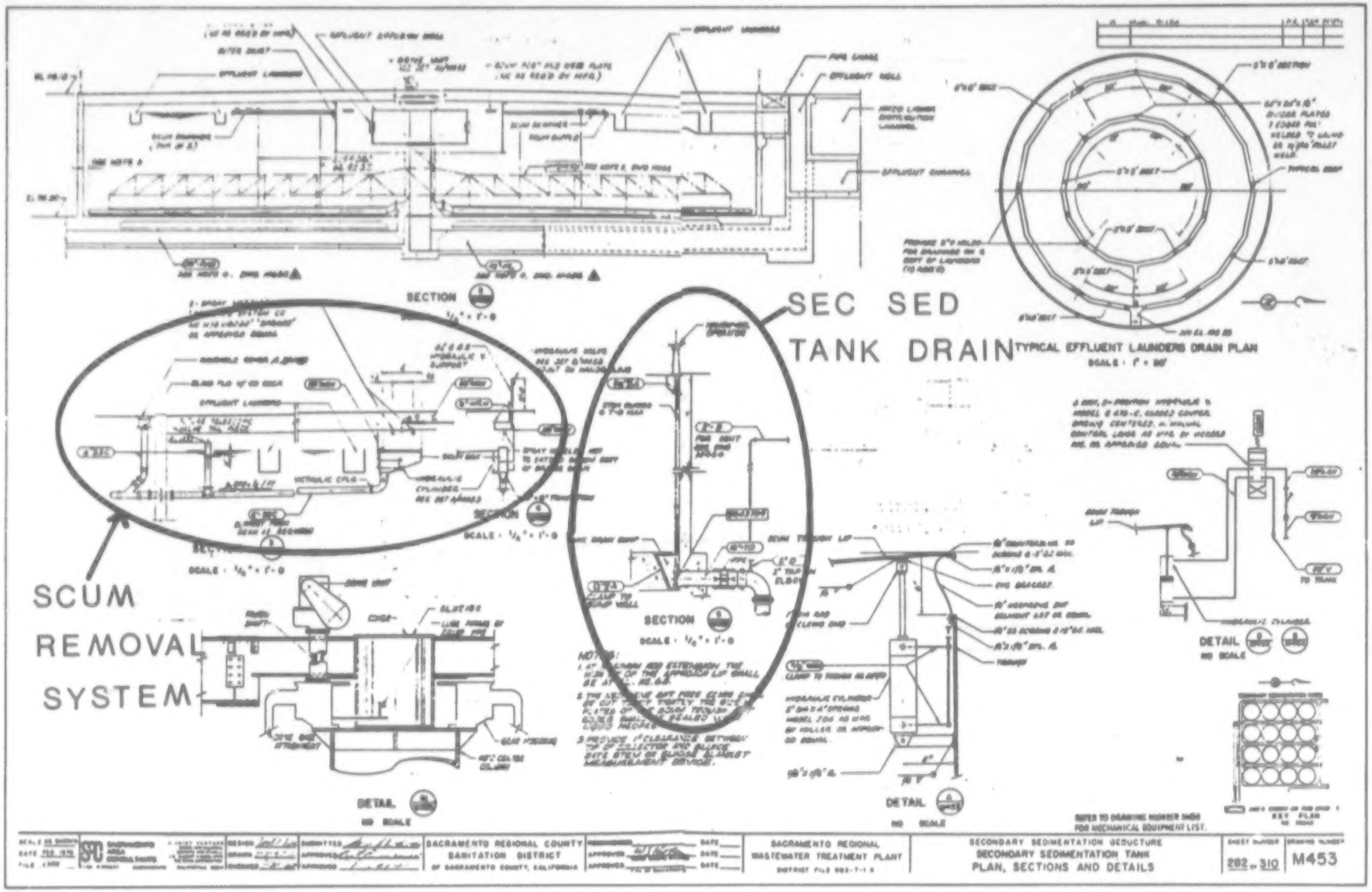

SEC SED
TANK DRAIN
SCUM
REMOVAL
SYSTEM
SECTION
SCALE · 1/4" = 1'-0
TYPICAL EFFLUENT LAUNDERS DRAIN PLAN
DETAIL
NO SCALE
EFFLUENT LAUNDERS
EFFLUENT CHANNEL
HYDRAULIC CYLINDER
SCUM TROUGH LIP
NOTES:
REFER TO DRAWING NUMBER 0455 FOR MECHANICAL EQUIPMENT LIST.
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT
OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
SECONDARY SEDIMENTATION STRUCTURE
SECONDARY SEDIMENTATION TANK
PLAN, SECTIONS AND DETAILS
202 of 310
M453

FIGURE 9.4 SKIMMERS USED FOR SCUM REMOVAL

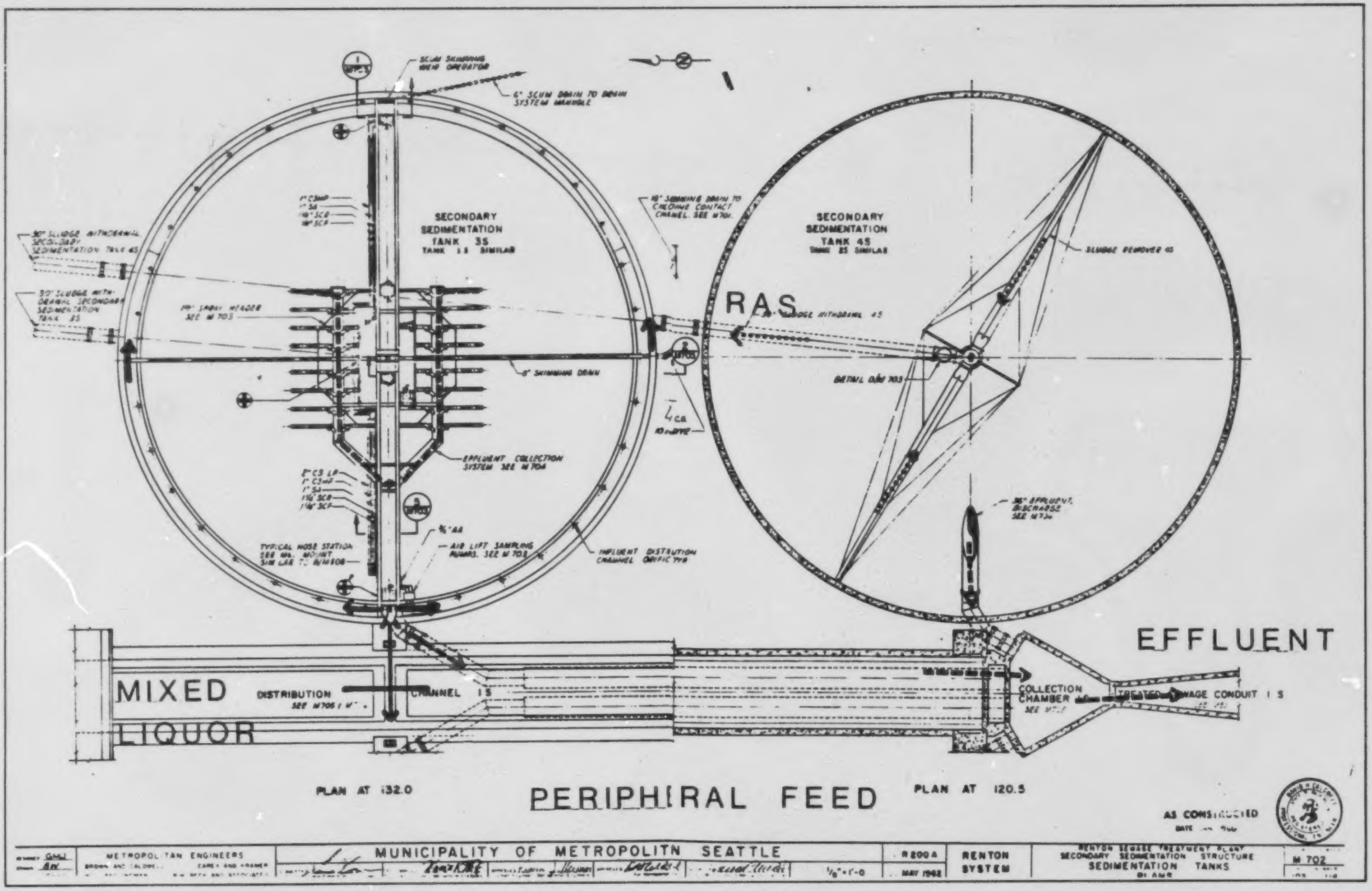

SCUM SKIMMING WEIR OPERATOR
6" SCUM DRAIN TO DRAIN SYSTEM MANHOLE
SECONDARY SEDIMENTATION TANK 3S
TANK 1S SIMILAR
SECONDARY SEDIMENTATION TANK 4S
TANK 2S SIMILAR
10" SKIMMING DRAIN TO CHLORINE CONTACT CHANNEL. SEE M701
30" SLUDGE WITHDRAWAL SECONDARY SEDIMENTATION TANK 4S
30" SLUDGE WITHDRAWAL SECONDARY SEDIMENTATION TANK 3S
1½" SPRAY HEADER SEE M 703
8" SKIMMING DRAIN
RAS
SLUDGE REMOVER 4S
DETAIL ON M 703
EFFLUENT COLLECTION SYSTEM SEE M 704
TYPICAL HOSE STATION SEE ML. MOUNT SIMILAR TO M/M508
AIR LIFT SAMPLING PUMPS. SEE M 703
INFLUENT DISTRIBUTION CHANNEL ORIFIC TYP
36" EFFLUENT DISCHARGE SEE M 704
EFFLUENT
MIXED LIQUOR
DISTRIBUTION CHANNEL 1S
COLLECTION CHAMBER
TREATED SEWAGE CONDUIT 1S
PLAN AT 132.0
PERIPHIRAL FEED
PLAN AT 120.5
AS CONSTRUCTED
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITN SEATTLE
1/8"=1'-0
R200A
MAY 1962
RENTON SYSTEM
RENTON SEWAGE TREATMENT PLANT
SECONDARY SEDIMENTATION STRUCTURE
SEDIMENTATION TANKS
PLANS
M 702

FIGURE 9.5 OVERFLOW WEIR NEAR CENTER OF TANK ON RIM FEED UNIT

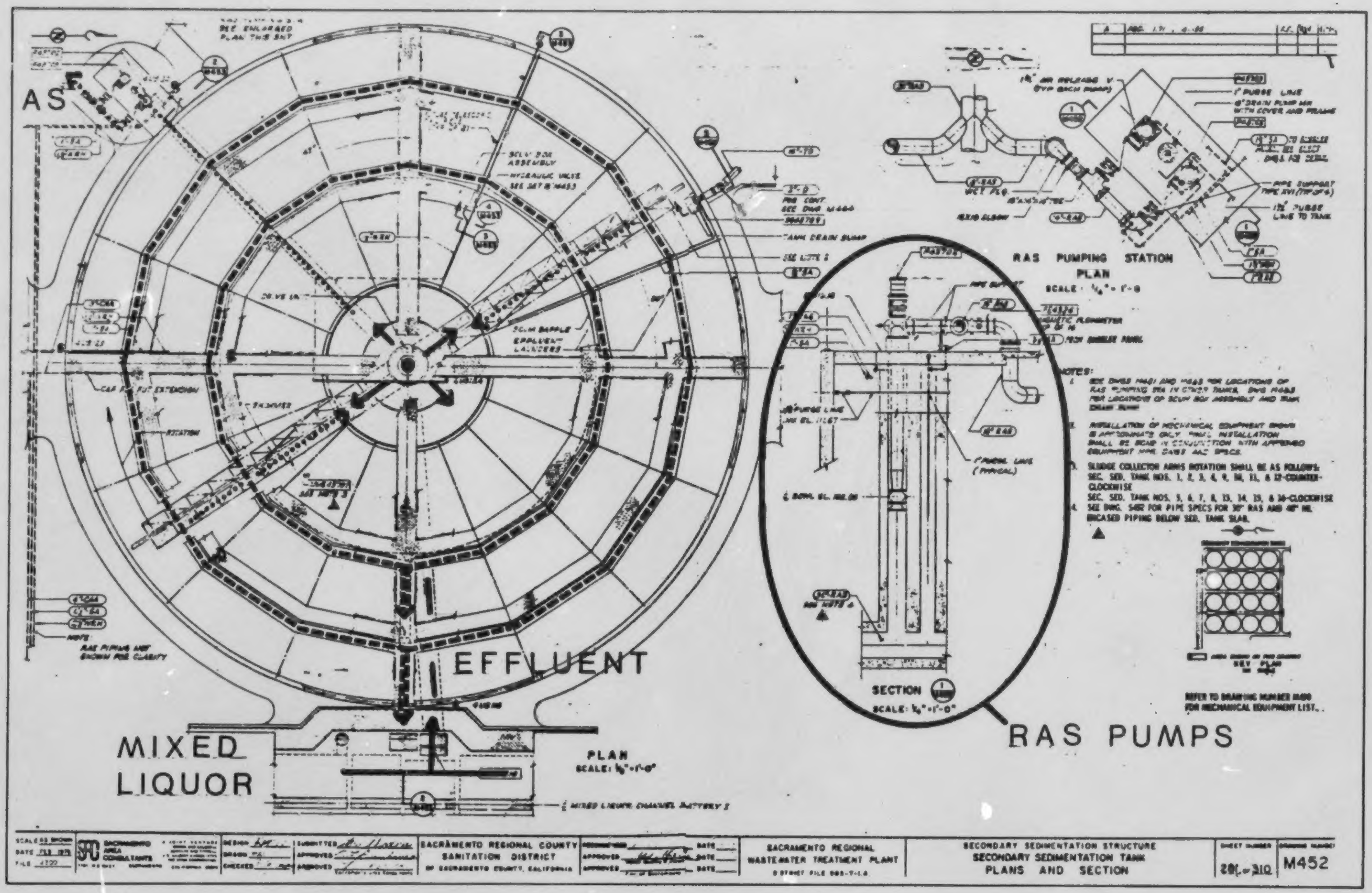

AS
EFFLUENT
MIXED LIQUOR
RAS PUMPS
RAS PUMPING STATION PLAN
SECTION
PLAN
SCALE: 1/8"=1'-0"
SCUM BAFFLE
EFFLUENT LAUNDERS
DRIVE UNIT
TANK DRAIN SUMP
ROTATION
SLUDGE COLLECTOR ARMS ROTATION SHALL BE AS FOLLOWS: SEC. SED. TANK NOS. 1, 2, 3, 4, 9, 10, 11, & 12-COUNTER-CLOCKWISE
SEC. SED. TANK NOS. 5, 6, 7, 8, 13, 14, 15, & 16-CLOCKWISE
SEE DWG. S482 FOR PIPE SPECS FOR 30" RAS AND 48" ML ENCASED PIPING BELOW SED. TANK SLAB.
REFER TO DRAWING NUMBER M400 FOR MECHANICAL EQUIPMENT LIST.
NOTE: RAS PIPING NOT SHOWN FOR CLARITY
MIXED LIQUOR CHANNEL BATTERY I
SACRAMENTO AREA CONSULTANTS
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
SECONDARY SEDIMENTATION STRUCTURE
SECONDARY SEDIMENTATION TANK
PLANS AND SECTION
M452

FIGURE 9.6 MINIMIZING UPFLOW VELOCITIES

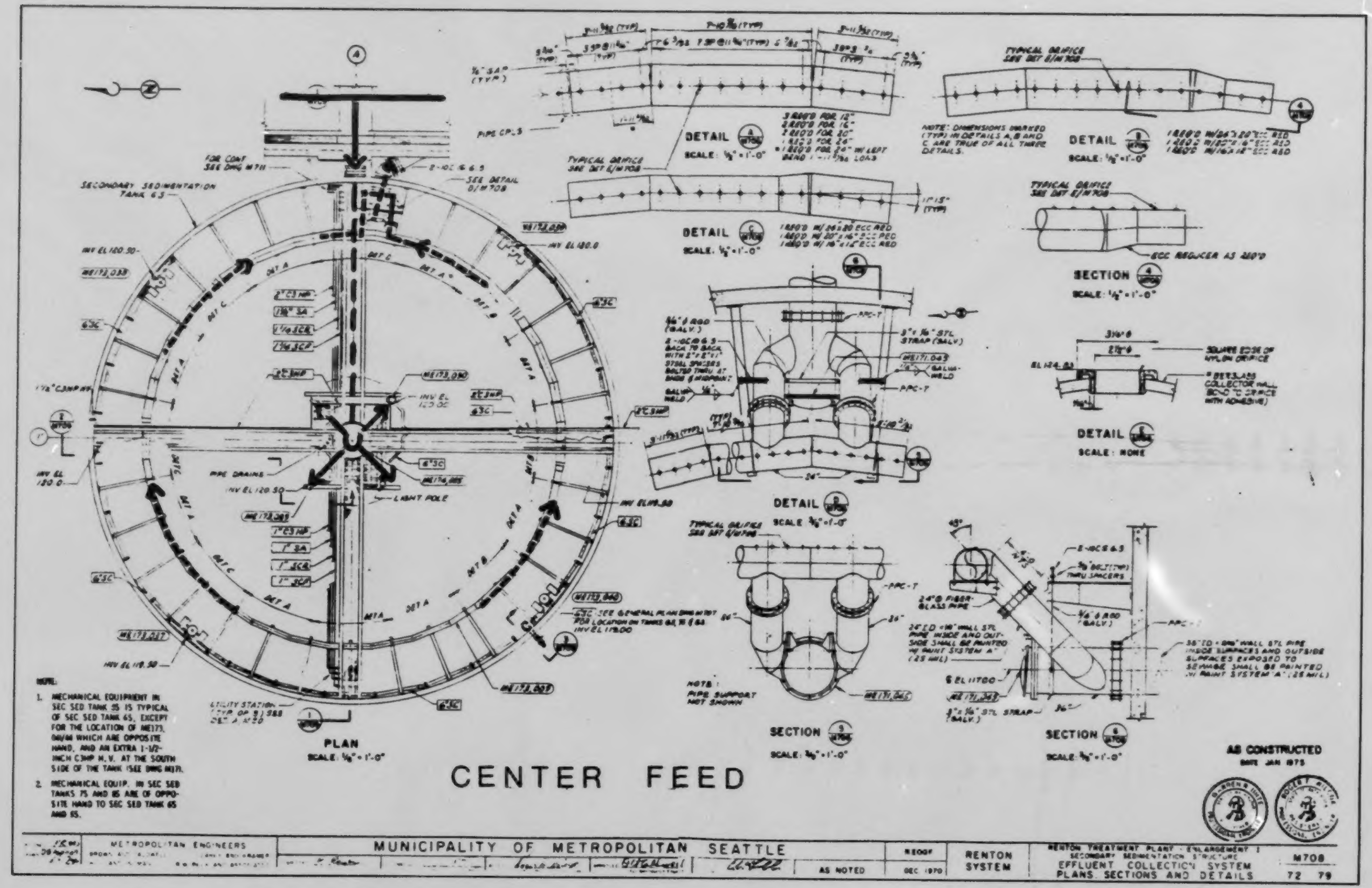

DETAIL A
SCALE: 1/2" = 1'-0"
DETAIL B
SCALE: 1/2" = 1'-0"
DETAIL C
SCALE: 1/2" = 1'-0"
TYPICAL ORIFICE SEE DET E/M708
PIPE CPLS
SECONDARY SEDIMENTATION TANK 6S
FOR CONT SEE DWG M711
SEE DETAIL D/M708
INV EL 120.50
INV EL 120.0
INV EL 119.50
PIPE DRAINS
LIGHT POLE
SECTION 4
SCALE: 1/2" = 1'-0"
ECC REDUCER AS REQ'D
SQUARE EDGE OF NYLON ORIFICE
DETAIL E
SCALE: NONE
DETAIL D
SCALE 3/8" = 1'-0"
PPC-T
SECTION 5
SCALE: 3/8" = 1'-0"
SECTION 6
SCALE: 3/8" = 1'-0"
NOTE: PIPE SUPPORT NOT SHOWN
PLAN
SCALE: 1/8" = 1'-0"
UTILITY STATION
NOTE:
1. MECHANICAL EQUIPMENT IN SEC SED TANK 5S IS TYPICAL OF SEC SED TANK 6S, EXCEPT FOR THE LOCATION OF ME173, 00/44 WHICH ARE OPPOSITE HAND, AND AN EXTRA 1-1/2-INCH C3WP H.V. AT THE SOUTH SIDE OF THE TANK (SEE DWG M171).
2. MECHANICAL EQUIP. IN SEC SED TANKS 7S AND 8S ARE OF OPPOSITE HAND TO SEC SED TANK 6S AND 5S.
CENTER FEED
AS CONSTRUCTED
DATE JAN 1975
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
AS NOTED
DEC 1970
RENTON SYSTEM
RENTON TREATMENT PLANT - ENLARGEMENT 1
SECONDARY SEDIMENTATION STRUCTURE
EFFLUENT COLLECTION SYSTEM
PLANS, SECTIONS AND DETAILS
M708
72 79

FIGURE 9.7 MINIMIZING UPFLOW VELOCITIES

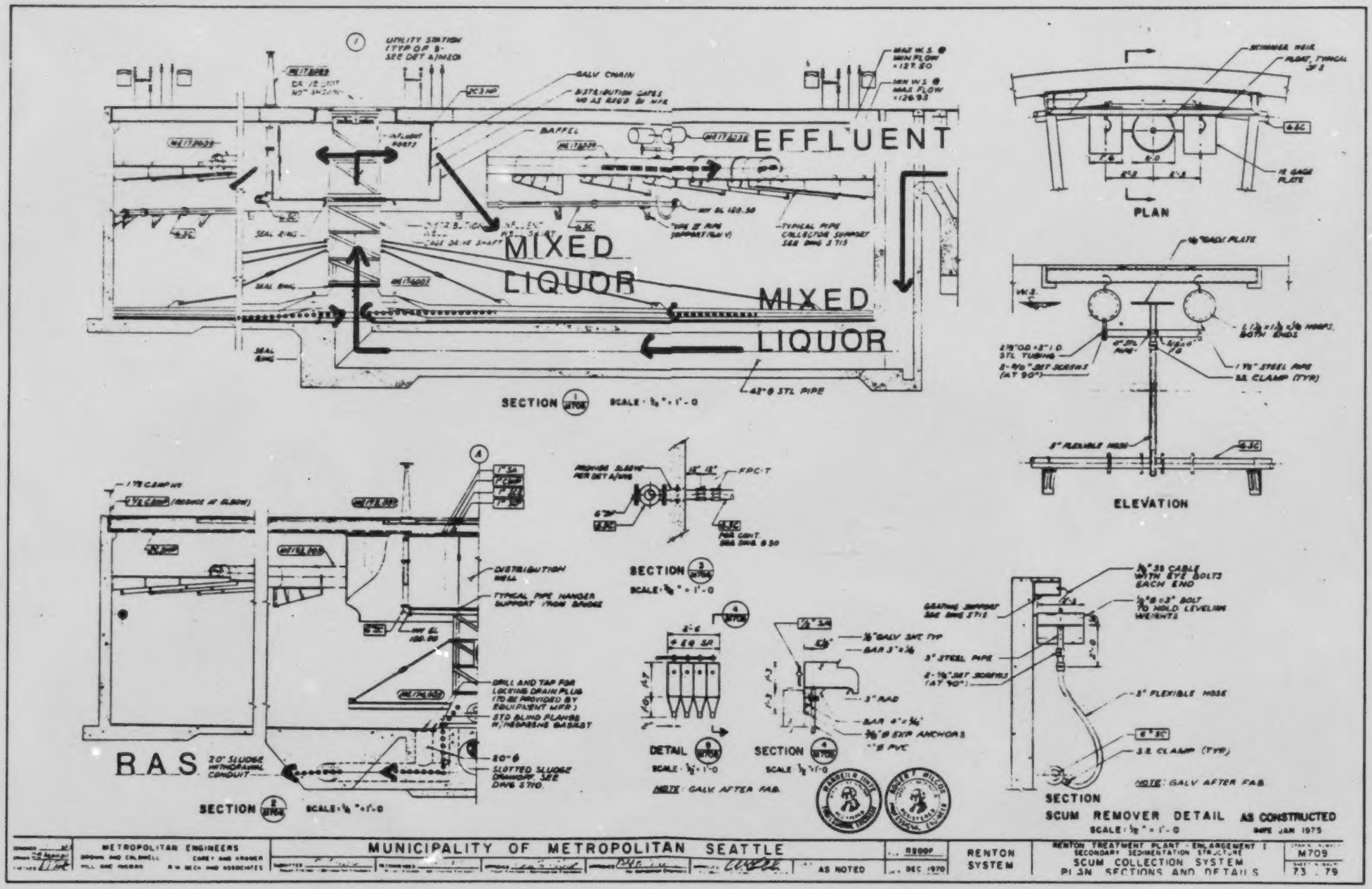

EFFLUENT
MIXED LIQUOR
MIXED LIQUOR
SECTION
PLAN
ELEVATION
B.A.S.
20" SLUDGE WITHDRAWAL CONDUIT
SLOTTED SLUDGE DRAWOFF. SEE DWG 5710.
SECTION
DETAIL
SECTION
SECTION
SCUM REMOVER DETAIL
AS CONSTRUCTED
NOTE: GALV AFTER FAB.
METROPOLITAN ENGINEERS
BROWN AND CALDWELL
COREY AND KRAMER
HILL AND INGMAN
R.W. BECK AND ASSOCIATES
MUNICIPALITY OF METROPOLITAN SEATTLE
AS NOTED
DEC 1970
RENTON SYSTEM
RENTON TREATMENT PLANT - ENLARGEMENT I
SECONDARY SEDIMENTATION STRUCTURE
SCUM COLLECTION SYSTEM
PLAN SECTIONS AND DETAILS
M709
73 79

FIGURE 9.8 HYDRAULIC COLLECTORS FOR SLUDGE COLLECTION

much higher return flow during low flow than at peak flow. Additionally, the orifices along the manifold should be sized differentially, as those along the edge of the tank will pick up more sludge than those near the center. The hydraulic capacity of the sludge removal equipment should be adequate to remove sludge from the entire tank bottom area during each revolution or pass.

Control over return and waste activated sludge is basic to the operation of an activated sludge treatment plant. It is important that the design of sludge handling facilities permit flexibility and reliability of operation so that treatment criteria are met and sludge is disposed of properly under all conditions.

Each group of aeration tanks and clarifiers should have its own separate return activated sludge (RAS) and waste activated sludge (WAS) facility with intergroup return and waste sludge capabilities (see Figure 9.9). The capacity to waste and return sludge concurrently should be a part of design. The operation should be designed with the capacity to handle 100 percent return of the sludge. This applies to all flow regimens to which the plant may be exposed. The design should include multiple pumps, with remote discharge control, that can provide this 100 percent return capacity with any single pump out of service (See Figure 9.10).

Suction and discharge piping on the RAS should be at least 4 inches diameter. Piping should be designed to maintain a sludge velocity of not less than 2 feet per second when the RAS facilities are operating at normal return rates. Return sludge piping may be terminated above the aeration tank liquid level to permit observation and sampling. All critical sludge transfer lines should be constructed in duplicate to allow for flexibility in rerouting sludge flow.

All activated sludge treatment plants, with the exception of small package plants, should be provided with an automatic RAS controller. The controller should be capable of sensing wastewater and return sludge flow, and for flexibility, the concentration of the MLSS and RAS. The operator, knowing process requirements from control test data, adjusts the controller set-point to the required RAS percentage, or preferably, the RAS concentration. The controller is then capable of regulating RAS discharge rates, continuously, to meet the process demands through normal wastewater flow variations.

Another type of automatic RAS controller can be designed utilizing a weir in the return line. The weir controls flow from a wet well in the return line. The weir governs the sludge pumping rate; when the head on the weir changes, the sludge flow rate changes accordingly. Thus, by calibrating the weir for the required percentage return flow, actual sludge flow rates will be automatically adjusted for this required percentage as wastewater flow changes diurnally (see Figure 9.11).

Flexibility in WAS operation should be a part of design. The WAS system should be able to waste a maximum capacity of not less than 25 percent of the average wastewater flow. This can be done by having either a large volume backup pumping system or a valved bypass between the WAS and RAS lines which permits the RAS system to be used temporarily for wasting.

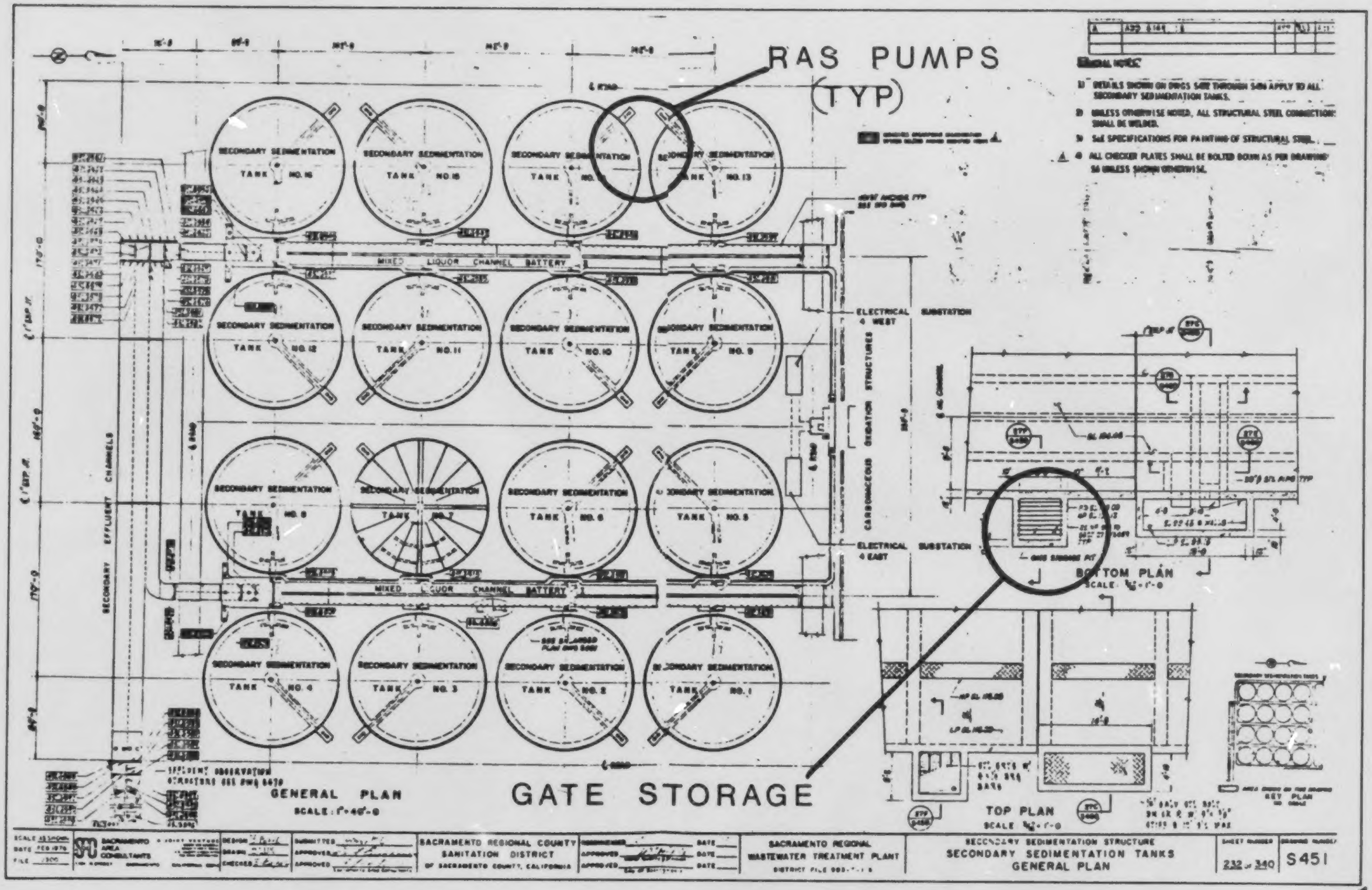

RAS PUMPS (TYP)
GATE STORAGE
SECONDARY SEDIMENTATION TANK NO. 16
SECONDARY SEDIMENTATION TANK NO. 15
SECONDARY SEDIMENTATION TANK NO. 13
SECONDARY SEDIMENTATION TANK NO. 12
SECONDARY SEDIMENTATION TANK NO. 11
SECONDARY SEDIMENTATION TANK NO. 10
SECONDARY SEDIMENTATION TANK NO. 9
SECONDARY SEDIMENTATION TANK NO. 8
SECONDARY SEDIMENTATION TANK NO. 7
SECONDARY SEDIMENTATION TANK NO. 6
SECONDARY SEDIMENTATION TANK NO. 5
SECONDARY SEDIMENTATION TANK NO. 4
SECONDARY SEDIMENTATION TANK NO. 3
SECONDARY SEDIMENTATION TANK NO. 2
SECONDARY SEDIMENTATION TANK NO. 1
MIXED LIQUOR CHANNEL BATTERY
SECONDARY EFFLUENT CHANNELS
CARBONACEOUS OXIDATION STRUCTURES
ELECTRICAL SUBSTATION 4 WEST
ELECTRICAL SUBSTATION 4 EAST
GENERAL PLAN
SCALE: 1"=40'-0
BOTTOM PLAN
TOP PLAN
KEY PLAN
SACRAMENTO AREA CONSULTANTS
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
SECONDARY SEDIMENTATION STRUCTURE
SECONDARY SEDIMENTATION TANKS
GENERAL PLAN
232 of 340
S451

FIGURE 9.9 FLEXIBILITY IN RETURN ACTIVIATED SLUDGE (RAS) PUMPING

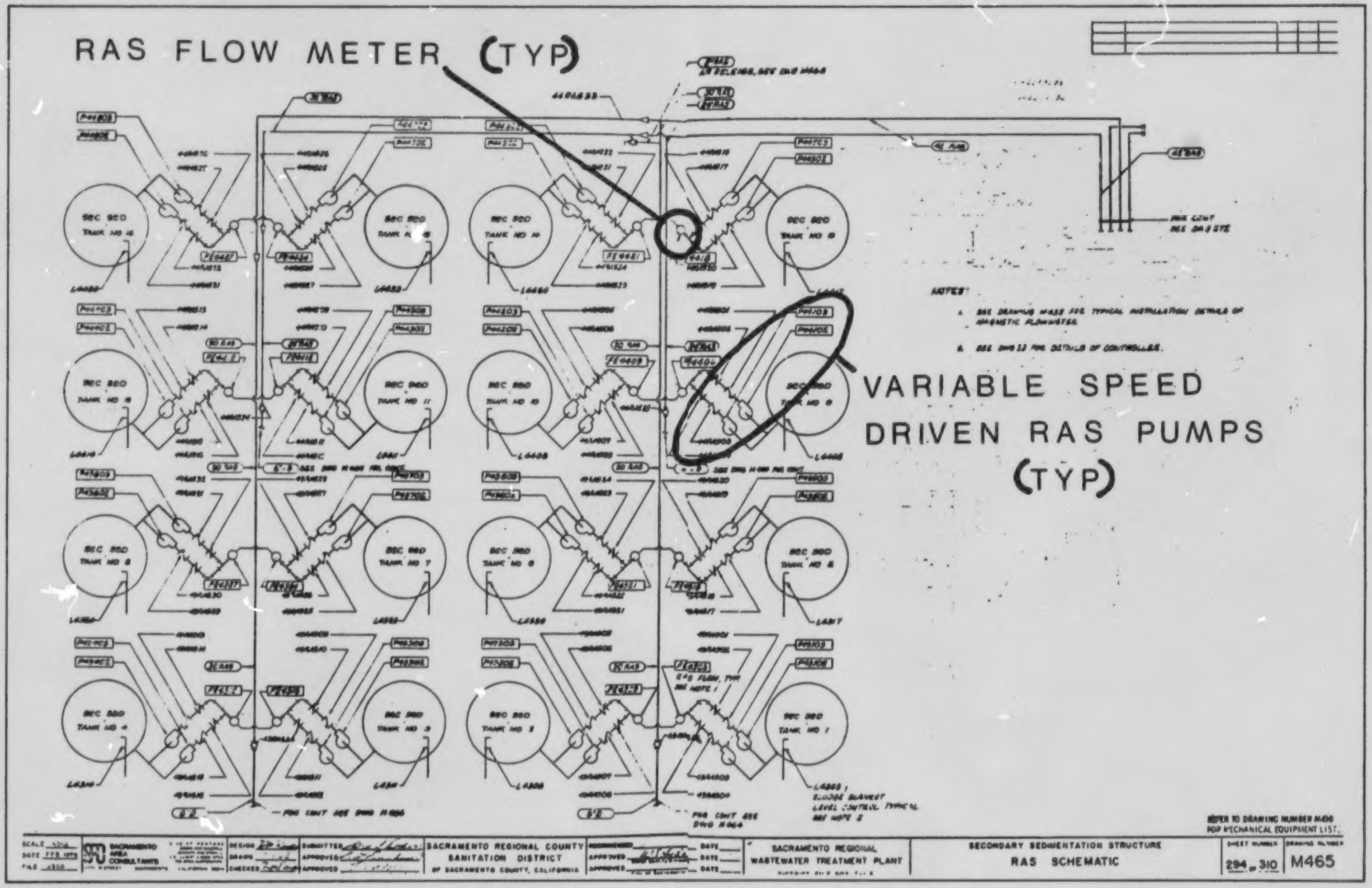

RAS FLOW METER (TYP)
VARIABLE SPEED DRIVEN RAS PUMPS (TYP)
SEC SED TANK NO 16
SEC SED TANK NO 15
SEC SED TANK NO 14
SEC SED TANK NO 13
SEC SED TANK NO 12
SEC SED TANK NO 11
SEC SED TANK NO 10
SEC SED TANK NO 9
SEC SED TANK NO 8
SEC SED TANK NO 7
SEC SED TANK NO 6
SEC SED TANK NO 5
SEC SED TANK NO 4
SEC SED TANK NO 3
SEC SED TANK NO 2
SEC SED TANK NO 1
NOTES:
SLUDGE BLANKET LEVEL CONTROL TYPICAL SEE NOTE 2
REFER TO DRAWING NUMBER M400 FOR MECHANICAL EQUIPMENT LIST.
SACRAMENTO AREA CONSULTANTS
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
SECONDARY SEDIMENTATION STRUCTURE
RAS SCHEMATIC
294 of 310
M465

FIGURE 9.10 VARIABLE PUMPS PROVIDE 100% RETURN CAPABILITY

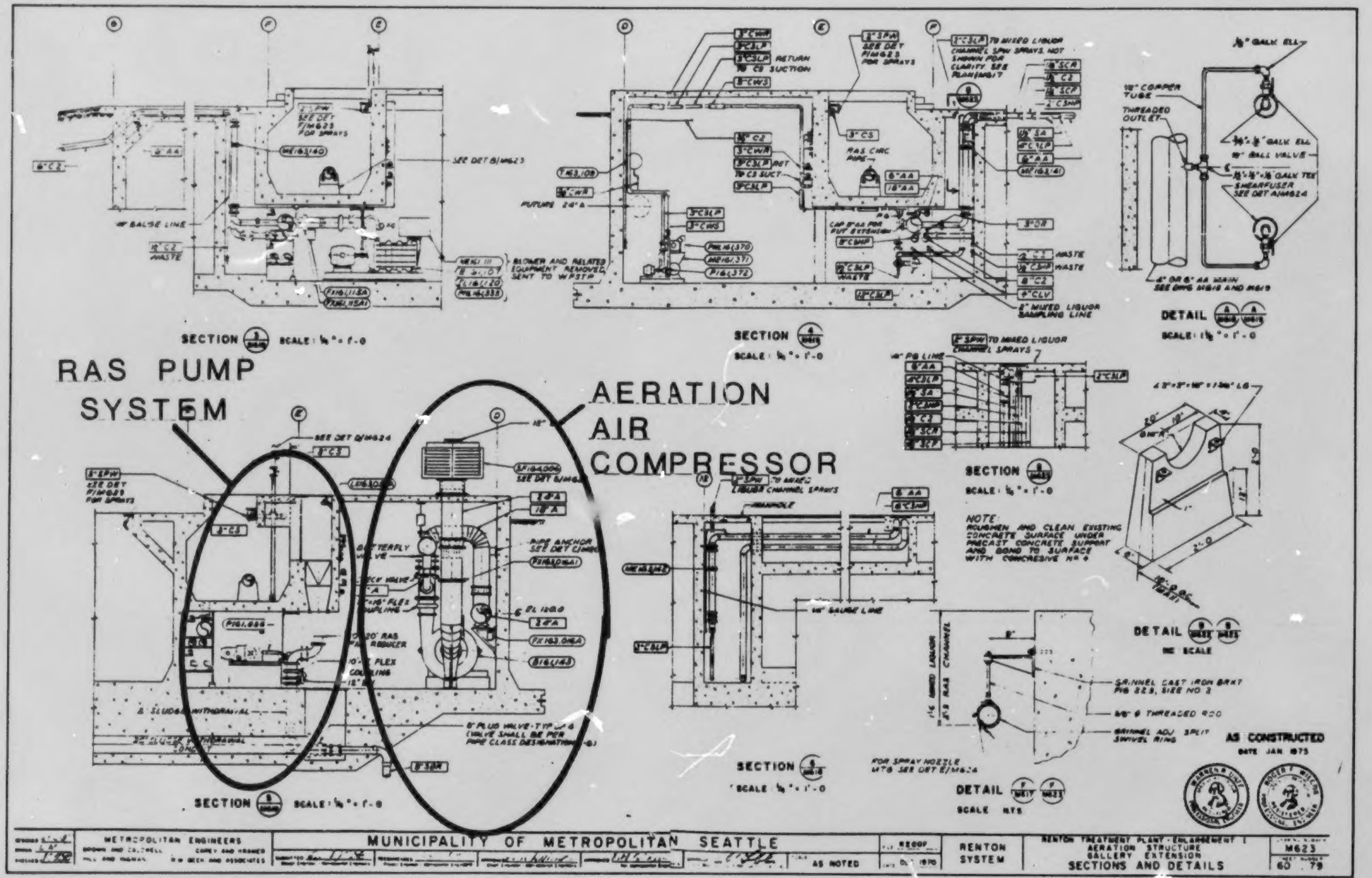

RAS PUMP SYSTEM
AERATION AIR COMPRESSOR
SECTION
SCALE: ¼" = 1'-0
DETAIL
SCALE: 1½" = 1'-0
SCALE NTS
NO SCALE
NOTE: ROUGHEN AND CLEAN EXISTING CONCRETE SURFACE UNDER PRECAST CONCRETE SUPPORT AND BOND TO SURFACE WITH CONCRESIVE Nº 4
BLOWER AND RELATED EQUIPMENT REMOVED, SENT TO WPSTP
FUTURE 24" A
RAS CIRC PIPE
BUTTERFLY VALVE
CHECK VALVE
FLEX COUPLING
20" RAS REDUCER
PIPE ANCHOR
16" SLUDGE LINE
MIXED LIQUOR SAMPLING LINE
GRINNELL CAST IRON BRKT FIG 323, SIZE NO 2
⅝" ø THREADED ROD
GRINNELL ADJ SPLIT SWIVEL RING
½" GALV ELL
½" COPPER TUBE
THREADED OUTLET
½" BALL VALVE
SHEARFUSER
AS CONSTRUCTED
DATE JAN 1975
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
AS NOTED
RENTON SYSTEM
RENTON TREATMENT PLANT - ENLARGEMENT I
AERATION STRUCTURE
GALLERY EXTENSION
SECTIONS AND DETAILS
M623
60 79

FIGURE 9.11 RETURN ACTIVATED SLUDGE (RAS) SYSTEM

The waste sludge pumps and meters should be sized small enough (3 to 10 percent of RAS flow) to assure proper wasting control. Both sludge concentration and flow measurements are needed for correct control. An automatic waste sludge controller that measures concentration and flow, converts to pounds or sludge units, and wastes the mass indicated by the operator's set-point adjustment, can improve plant performance.

WAS removal should be self-correcting to adjust automatically for changes in sludge consistency (see Figure 9.12). This system should be independent of changes that may occur in the return sludge system. Reliance should not be made on sidestreams off the RAS piping without separate control for WAS. The design should avoid branching the waste sludge line off a common return-waste discharge header. Separate return and waste pumps should be used.

Flexibility in WAS facility design can be achieved by providing emergency storage for waste sludge. For example, a tee and valve can be added to the WAS line to route sludge to the primary clarifiers in the event that disposal capabilities are temporarily reduced.

G. Maintenance and Repair

Maintenance and repair are important considerations in secondary sedimentation design. Adequate provision for taking settling tanks out of service will encourage proper maintenance of these units. A transfer pump and piping system designed to empty any tank within an 8-hour shift is recommended. Protection against loss of solids can be achieved by insuring that sedimentation tank contents can be pumped into the aeration basins.

If hydraulic draw-off of sludge is used, then it may be difficult to put a drain in the center of the tank. In this case, a bottom which slopes toward the periphery of the tank may be appropriate. Drains can be located at the periphery for easy cleaning of the tank.

All portions of the secondary sedimentation system should be capable of being isolated for maintenance and repairs. Inlets and outlets should be sealed off with slide or sluice gates. Adequate washdown water should be provided. Steam cleaning and compressed air may be useful. 120/240/440 volt utility power outlets are helpful.

H. Design and Operational Criteria for Thickening of Biological Sludges

A more detailed discussion of the set point (or state point) and its application to the analysis of design parameters is presented as Appendix 9A.

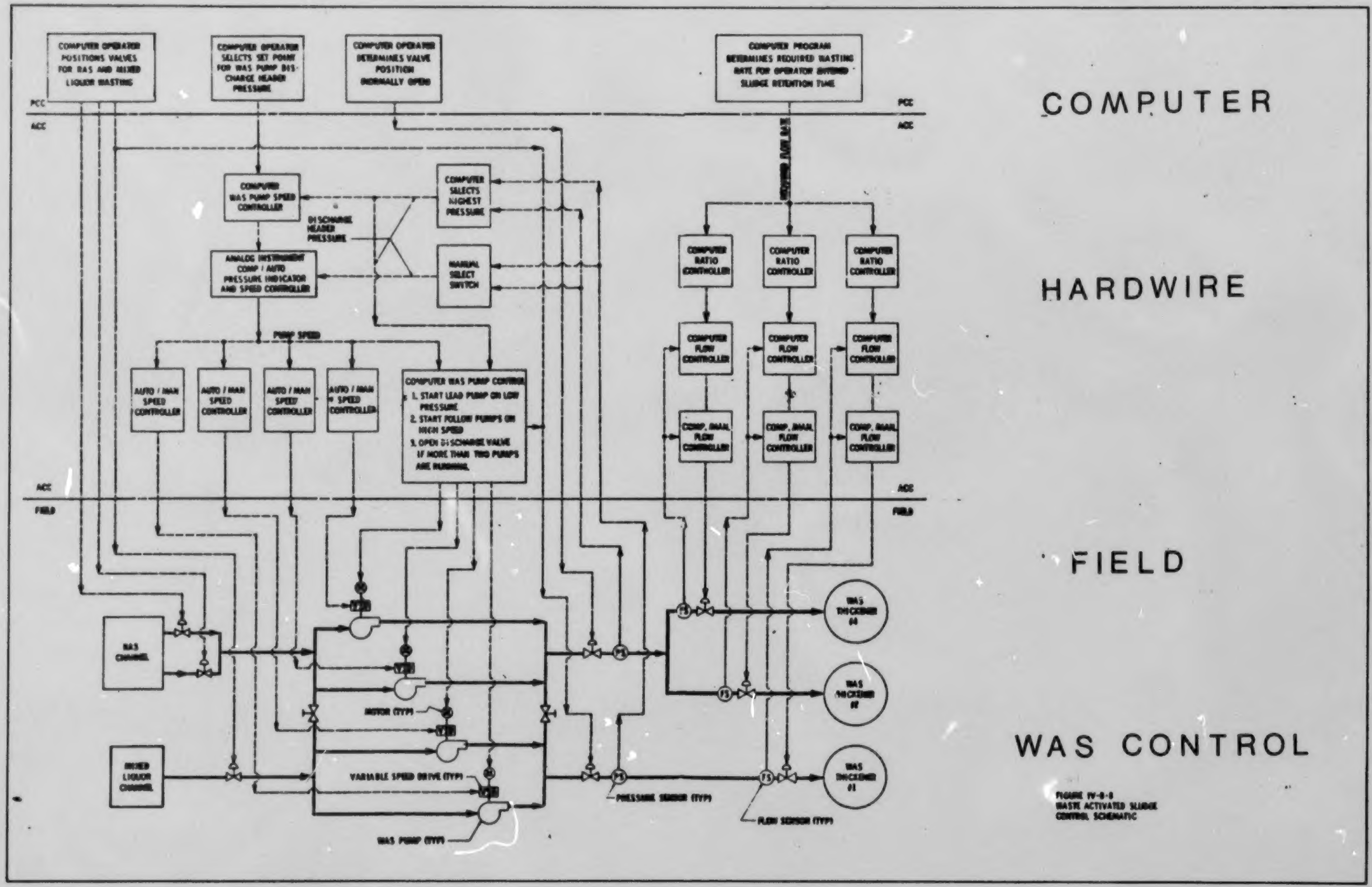

COMPUTER OPERATOR POSITIONS VALVES FOR RAS AND MIXED LIQUOR WASTING
COMPUTER OPERATOR SELECTS SET POINT FOR WAS PUMP DISCHARGE HEADER PRESSURE
COMPUTER OPERATOR DETERMINES VALVE POSITION (NORMALLY OPEN)
COMPUTER PROGRAM DETERMINES REQUIRED WASTING RATE FOR OPERATOR ENTERED SLUDGE RETENTION TIME
PCC
ACC
REQUIRED FLOW RATE
COMPUTER WAS PUMP SPEED CONTROLLER
COMPUTER SELECTS HIGHEST PRESSURE
DISCHARGE HEADER PRESSURE
ANALOG INSTRUMENT COMP / AUTO PRESSURE INDICATOR AND SPEED CONTROLLER
MANUAL SELECT SWITCH
PUMP SPEED
AUTO / MAN SPEED CONTROLLER
AUTO / MAN SPEED CONTROLLER
AUTO / MAN SPEED CONTROLLER
AUTO / MAN SPEED CONTROLLER
COMPUTER WAS PUMP CONTROL
1. START LEAD PUMP ON LOW PRESSURE
2. START FOLLOW PUMPS ON HIGH SPEED
3. OPEN DISCHARGE VALVE IF MORE THAN TWO PUMPS ARE RUNNING
COMPUTER RATIO CONTROLLER
COMPUTER RATIO CONTROLLER
COMPUTER RATIO CONTROLLER
COMPUTER FLOW CONTROLLER
COMPUTER FLOW CONTROLLER
COMPUTER FLOW CONTROLLER
COMP. MAN. FLOW CONTROLLER
COMP. MAN. FLOW CONTROLLER
COMP. MAN. FLOW CONTROLLER
ACC
FIELD
RAS CHANNEL
MIXED LIQUOR CHANNEL
MOTOR (TYP)
VARIABLE SPEED DRIVE (TYP)
WAS PUMP (TYP)
PS
PS
PRESSURE SENSOR (TYP)
FS
FS
FS
FLOW SENSOR (TYP)
WAS THICKENER #3
WAS THICKENER #2
WAS THICKENER #1
COMPUTER
HARDWIRE
FIELD
WAS CONTROL
FIGURE IV-8-8
WASTE ACTIVATED SLUDGE CONTROL SCHEMATIC

FIGURE 9.12 AUTOMATED WASTE ACTIVATED SLUDGE (WAS) CONTROL

APPENDIX 9A

DESIGN AND OPERATIONAL CRITERIA FOR THICKENING OF BIOLOGICAL SLUDGES

UNIT 9A - DESIGN AND OPERATIONAL CRITERIA FOR THICKENING OF BIOLOGICAL SLUDGES

APPENDIX 9A

OBJECTIVES

At the conclusion of this presentation, the participant shall able to:

- Implement the batch settling flux system to the clarification and thickening processes, utilizing appropriate background and theoretical considerations in selecting the appropriate apparatus for performing each system.
- Identify the basis of aerator design with respect to solids residence time.
- Identify the basis of clarification design with respect to the constraints of overflow rate and the data developed by Pflanz and Agnew.
- Analyze the effect of increased and decreased hydraulic flow rates on thickening with and without control measures.
- Analyze the effects of flow proportional control on clarifier/thickener performance.
- Analyze the effects of concentrated MLSS with no overload, minor overload, major overload, and high recirculation rates on the control of clarification.
- Analyze the change in sludge settling characteristics and identify methods of control.
- Analyze the effects of solids residence time on thickening characteristics and identify control measures.

OUTLINE

I. BACKGROUND AND THEORETICAL CONSIDERATION 7-3

A. Introduction
B. Bio-solids sedimentation
C. Batch settling flux approach
D. Solids concentration profiles
E. State point concept
F. Experimental approach and apparatus

II. SYSTEM DESIGN 7-17

A. Inter-changeable units
B. Design basis/aerator
C. Design basis/clarifier 7-21
D. Illustrative design example 7-26

III. OPERATIONAL STATE ANALYSIS AND CONTROL 7-30

A. Operations objectives
B. Variable influent flow rate (thickening considerations) 7-34
C. Variable influent flow rate (clarification considerations) 7-39
D. Changes in sludge settling characteristics 7-48
E. Changes in solids residence times 7-49
F. On-line, real-time determination of settling flux curves 7-50

IV. REFERENCES

V. AUTHOR CITATION 7-54

DESIGN AND OPERATIONAL CRITERIA FOR THICKENING OF BIOLOGICAL SLUDGES

I. BACKGROUND AND THEORETICAL CONSIDERATIONS

A. Only a brief introduction to the theory of thickening is included here. For a comprehensive treatment, the student is referred to Dick (7) or Vesilind (3). The basic activated sludge system considered in this development is shown diagramatically in Figure 1.

B. Bio-Solids Sedimentation

1. Bio-solids that are introduced into a clarifier are transported to the bottom by two velocity components (see Figure 2): v, the gravitational sedimentation component and u, the component due to withdrawal of solids in the underflow ($u = R/A$). The solids transport flux due to the former, termed settling flux, is defined as the product of the solids concentration and settling velocity.

$$G_s = c * v \qquad (1)$$

The solids flux due to the latter, termed the bulk flux, is equivalent to the product of the solids concentration and the bulk underflow withdrawal velocity.

$$G_b = c * u \qquad (2)$$

The total transport flux, therefore, is given by the sum of the two components.

$$G = G_s + G_b \qquad (3)$$

All parameters ae defined in the section entitled Notation.

2. Schematically, the two flux components and the total flux can be represented as shown in Figures 3 and 4, respectively. A minimum in the total flux curve can be observed in Figure 4. This, termed the limiting flux, G_L, is the maximum solids flux that can be transmitted to the bottom of the clarifier. The limiting flux establishes the solids handling capacity of the clarifier.

C. Batch Settling Flux Approach

1. A geometric technique developed by Yoshioka et al. (1) allows one to determine the limiting flux simply by drawing a line tangent to the settling flux curve which intersects the x-axis at the desired value of underflow solids concentration, C_u (Figure 5). This line has a slope of minus u. Similarly, a line drawn from the origin to any point on the settling flux curve has slope of v. This is the settling velocity of the solids at the concentration that corresponds to the x-coordinate of the point of intersection.

2. Figure 6 illustrates the analogy between the total flux curve (Figure 4) and the geometric technique developed by Yoshioka, et al. (1). The latter approach has been employed in this development because it offers the advantages of simplicity and versatility of application.

D. Solids Concentration Profiles

1. Solids concentration profiles that exist in operating prototype secondary clarifiers can be approximated using the batch settling flux curve. This requires the construction of an operating line which has a Y-intercept equal to the applied flux, $C_o (Q_i + R)/A$, and a slope of u, R/A. As noted above, the X-intercept should be equal to the suspended solids concentration in the underflow of the clarifier, C_u.

2. Three illustrative operating lines have been constructed on the batch settling flux plot shown in Figure 7. The operating line for Case A is shown tangent to the batch flux curve. For such a condition the clarifier is critically loaded; i.e. the mass flow of solids entering the clarifier is equal to the maximum rate at which solids can be transmitted to the bottom.

For this case one would expect to observe three stable suspended solids "blankets" of differenct concentrations. Figure 8 shows the expected concentration vs. depth profile. The three stable concentrations shown C'_L, C_L, and C_u, correspond to the concentration defined by the intersection of the operating line with the rising limb of the batch curve, the point of tangency of the operating line and the batch flux curve and the intersection of the operating line and the x-axis, respectively. The upper dilute blanket, C'_L, would be expected to extend downward from the clarifier feed point to the thick blanket, C_L. The upper dilute blanket, however, may not form if the solids are flocculent. In such cases the solids would fall from the feed point as an "underwater waterfall" to the point at which they are incorporated into the thick blanket as illustrated in Figure 2. The zone of concentration C_u would exist only near the bottom of the clarifier.

3. In an underloaded clarifier, Case B, only two stable blankets would be expected to form: the upper dilute blanket of concentration C'_L and the underflow zone of concentration C_u. Both C'_L and C_u are less than the corresponding concentrations for Case A (see Figures 7 and 8).

4. An overloaded clarifier, Case C, is described by the dashed operating line in Figure 7

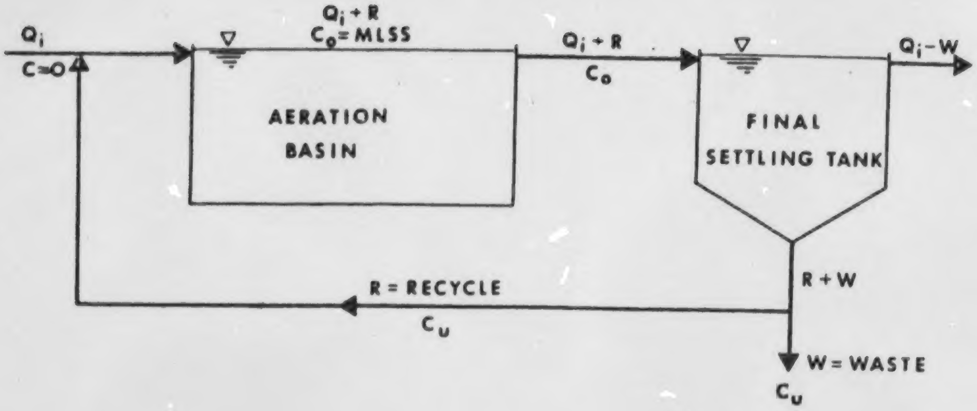

Q_i
$C=0$
$Q_i + R$
C_o = MLSS
AERATION BASIN
$Q_i + R$
C_o
FINAL SETTLING TANK
$Q_i - W$
R + W
R = RECYCLE
C_u
W = WASTE
C_u

FIGURE 1 Schematic of Activated Sludge System

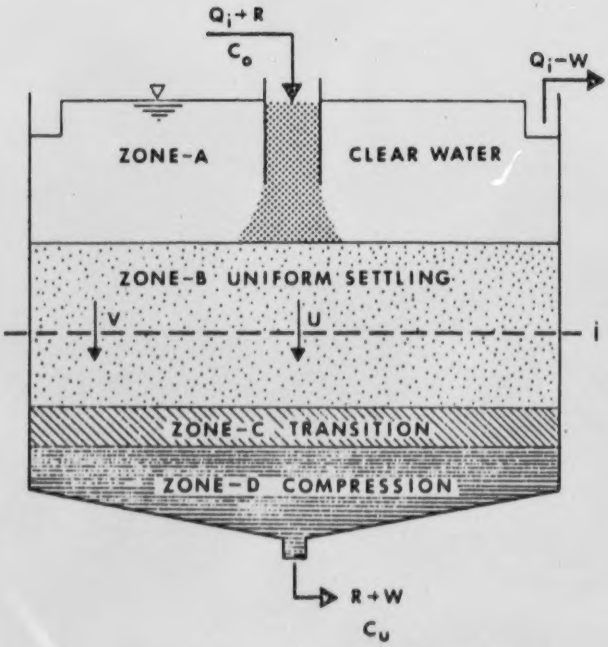

$Q_i + R$
C_o
$Q_i - W$
ZONE-A
CLEAR WATER
ZONE-B UNIFORM SETTLING
V
U
i
ZONE-C TRANSITION
ZONE-D COMPRESSION
R + W
C_u

FIGURE 2 Cross-Section of Secondary Clarifier

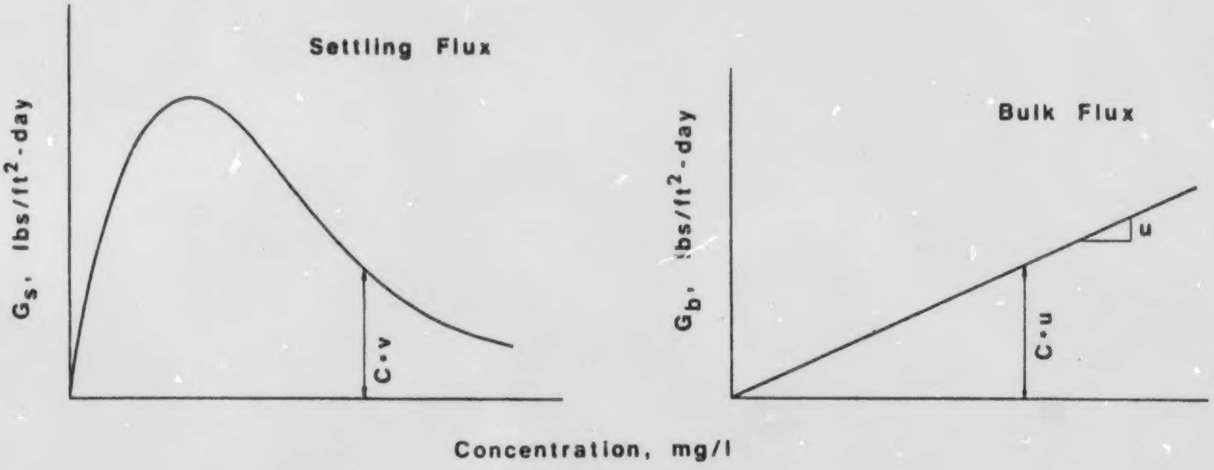


FIGURE 3 Settling and Bulk Flux Solids Transport Components

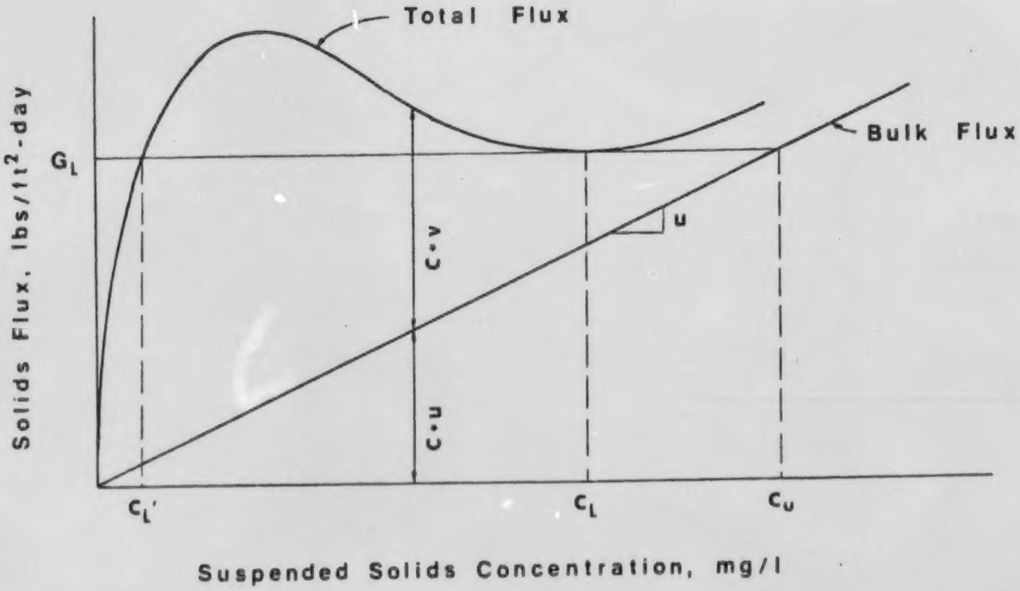


FIGURE 4 Total Flux Curve For Sedimentation

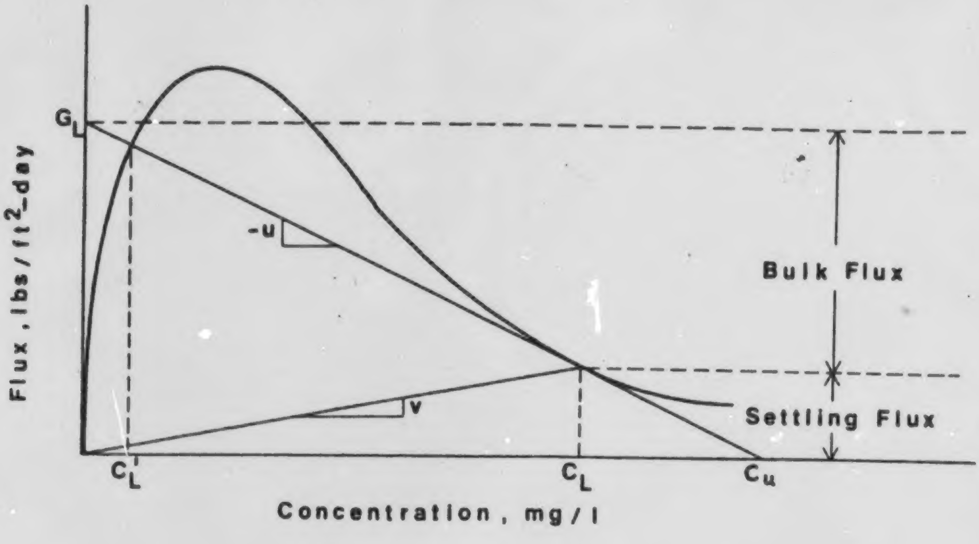

G_L
Flux, lbs/ft²-day
-u
v
Bulk Flux
Settling Flux
C_L'
C_L
C_u
Concentration, mg/l

FIGURE 5 Batch Settling Flux Analytical Method

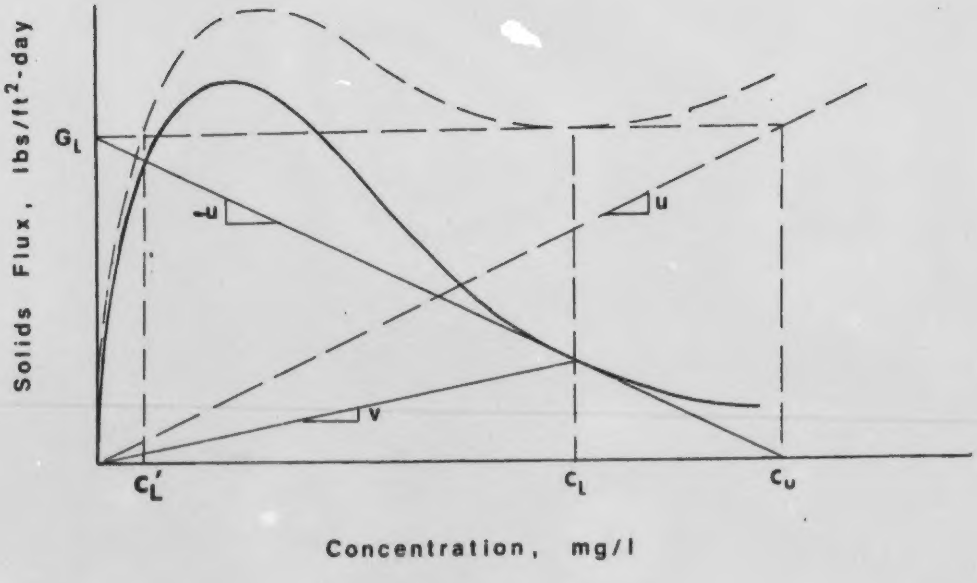

G_L
Solids Flux, lbs/ft²-day
-u
u
v
C_L'
C_L
C_u
Concentration, mg/l

FIGURE 6 Batch and Total Settling Flux Curves

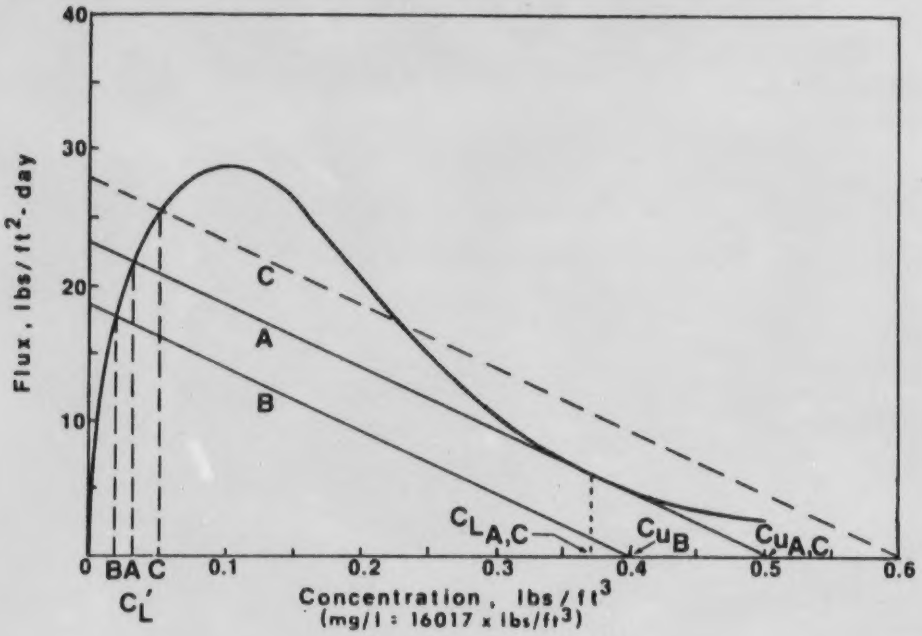


FIGURE 7 Clarifier Analysis For Three Loading Cases

which passes above the batch settling flux curve. Because the clarifier is able to transmit only the limiting flux to the bottom, all solids applied to the clarifier in excess of the limiting flux must accumulate within the clarifier. This occurs by the upward propagation of the blanket of concentration C_L. Ultimately the blanket propagates upward to the point where the excess solids are scoured from the blanket and are discharged over the weirs of the clarifier. In this case the upper dilute blanket of concentration C'_L occurs only during the period that the thick blanket below the feed point. It is to be noted that the concentrations C_L and C_u are the same as those that would be observed in the critically loaded case.

5. Although the concentration profiles shown in Figure 8 have been illustrated as being discontinuous ("squared") in shape, the actual profiles generally are considerably rounded; that is, the concentration gradients are not as pronounced as illustrated. This occurs because of hydraulic solids dispersion in the clarifier.

E. State Point Concept

1. For design and operations analysis it is desirable to introduce the concept of a state point, first defined by McHarg (4). The state point is defined by the intersection of two operating lines on the batch flux plot.

2. One the lines (recycle-rate operating line) has a slope of minus u and describes the recycle flow from the clarifier to the aerator (Figure 9).

3. The other (overflow-rate operating line) begins at the origin and has a slope equivalent to the clarifier overflow rate, Q_i/A expressed in feet per day. Actually the clarifier overflow rate is equal to $(Q_i - W)/A$. Since W is usually less than 3 percent of Q_i, the overflow rate can be approximated by Q_i/A without appreciable error.

4. Accordingly, the state point has a y-coordinate of G_o which is the solids flux, $(C_o * Q_i)/A$, imposed on the clarifier due to influent flow and an x-coordinate of C_o the mixed liquor suspended solids concentration. It must be emphasized the C_o is not intrinsically a concentration that one would expect to observe in the clarifier. Nonetheless, either the dilute or thick blankets could have a concentration equal to C_o under certain operating conditions.

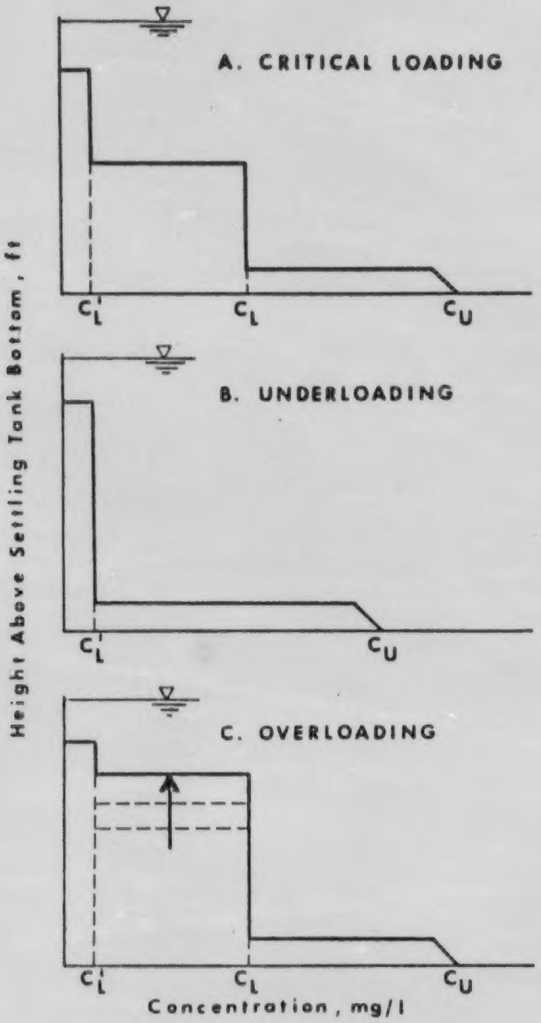

A. CRITICAL LOADING
B. UNDERLOADING
C. OVERLOADING
C_L'
C_L
C_U
Height Above Settling Tank Bottom, ft
Concentration, mg/l

FIGURE 8 Solids Concentration Profiles

5. Changes in recycle flow rate:

   a. To illustrate the utility of the state point concept two examples are instructive. Figure 10 shows that the state point serves as a pivot for the situation in which the recycle flow rate is changed. By decreasing the recycle flow rate the slope of the recycle rate operating line also decreases proportionately; i.e. $u_4 < u_3 < u_2 < u_1$.

   b. It is to noted, furthermore, that the dashed recycle rate operating line with slope u_4 passes above the batch settling flux curve. This indicates that recycle flow rate has been decreased to the extent that the clarifier is overloaded with respect to its thickening capacity. This would result in the transfer of bio-solids would be stored in the clarifier in the form of a solids "blanket" of approximate concentration C_L. The blanket would propagate upward in the clarifier to accommodate the solids transferred. If the overloaded condition prevailed for an extended period of time, the clarifier

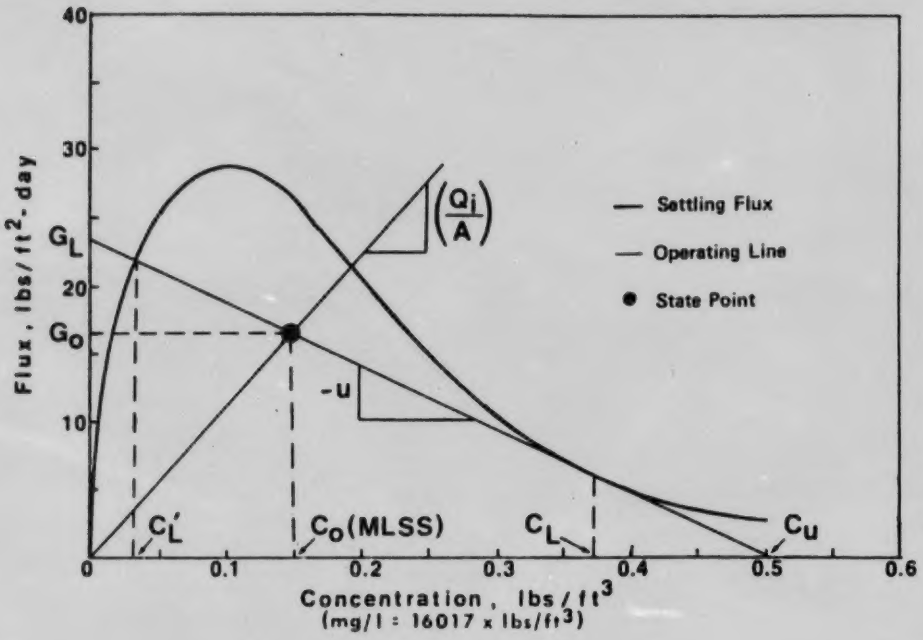


FIGURE 9 Batch Settling Flux Curve With Operating Lines and State Point

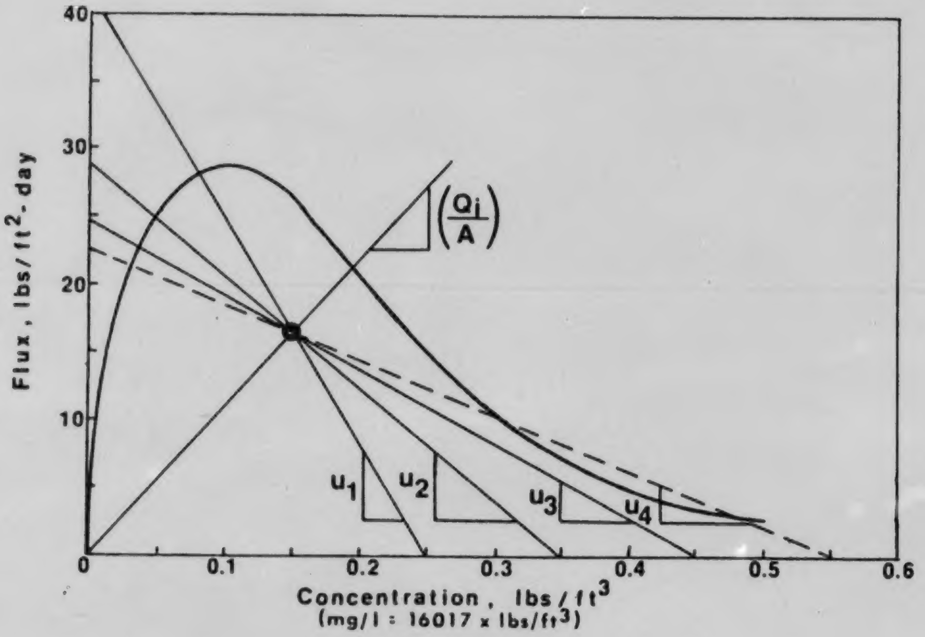


FIGURE 10 Batch Settling Flux Curve With Four Recycle Rate Operating Lines

would ultimately fail by scouring solids from the blanket and discharging them over the weirs. This overload condition could be relieved by increasing the recycle rate such that the recycle operating line does not pass above the settling flux curve.

6. Changes in influent flow rate:

   a. Diurnal changes in the influent flow rate to the activated sludge system change the location of the state point as may be observed in Figure 11. Shown are influent overflow rate operating lines for three cases of diurnal flow rate: (Q_i/A) max. (Q_i/A) avg. and (Q_i/A) min. All three recycle rate operating lines are parallel to one another because the recycle flow rate was not changed. The state point is seen to shift from one (Q_i/A) operating line to another at constant C_o (MLSS). An increase in the influent flow rate to the system does not have a priority result in a redistribution of bio-solids between the aerator and clarifier.

   b. As in the previous case, the dashed recycle rate operating line passes above the batch flux settling curve indicating an overloaded condition. This could be resolved, as before, by increasing the recycle flow rate such that the recycle operating line is rotated to the point of tangency. Otherwise some bio-solids would be transferred from the aerator to the clarifier causing the thick "blanket" to rise in the clarifier while the solids concentration in the aerator becomes more dilute.

F. Experimental Approach and Apparatus

1. Test procedures

   a. Use of the batch flux approach requires experimental development of settling flux curves. This is accomplished by determining the initial interface settling velocities (ISV's) of a representative sludge sample at different initial concentrations.

   b. Interface settling curves that were obtained for a sludge obtained from an extended aeration activated sludge treatment plant have been plotted in Figure 12 for initial suspended solids concentrations ranging from 3122 to 13,497 mg/l.

   c. Initial settling velocities are determined from the slope of the linear segment of the traces. In doing so it is important to exclude the curved portion of the traces where the settling

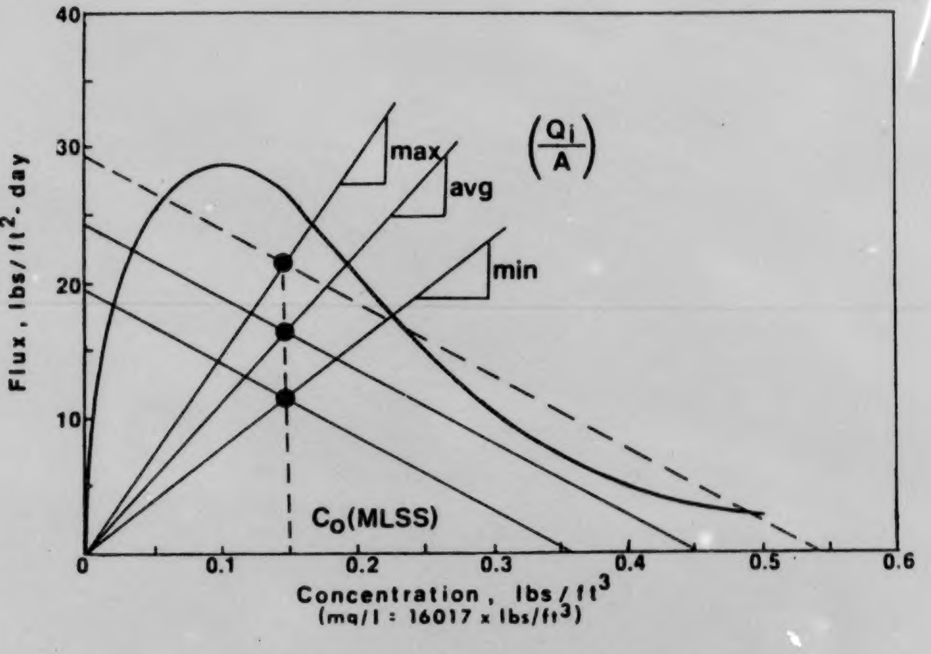


FIGURE 11 Batch Settling Flux Curve With Three Overflow Rate Operating Lines

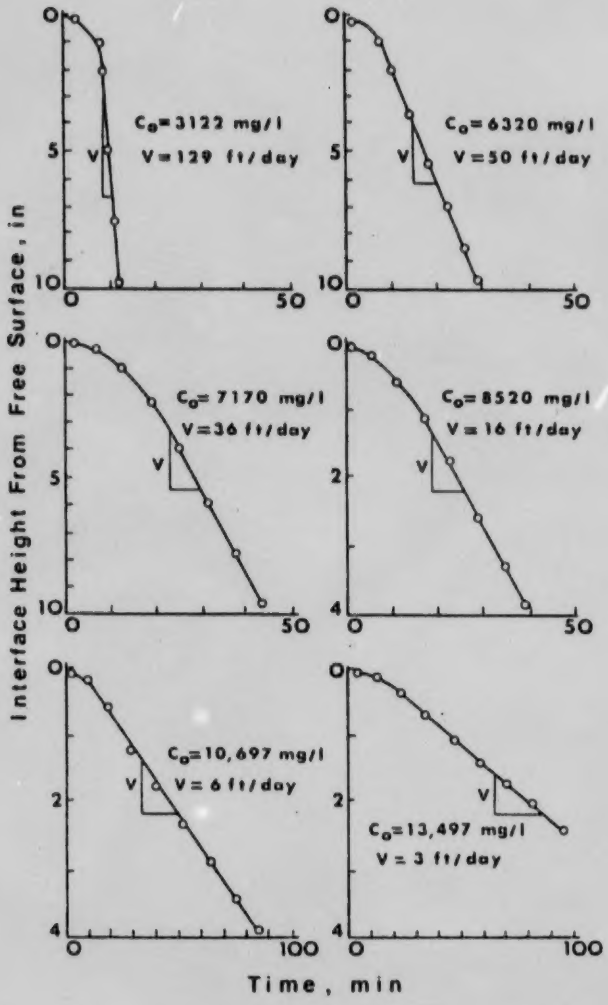


FIGURE 12 Solids/Liquid Intarface Height vs. Time Traces

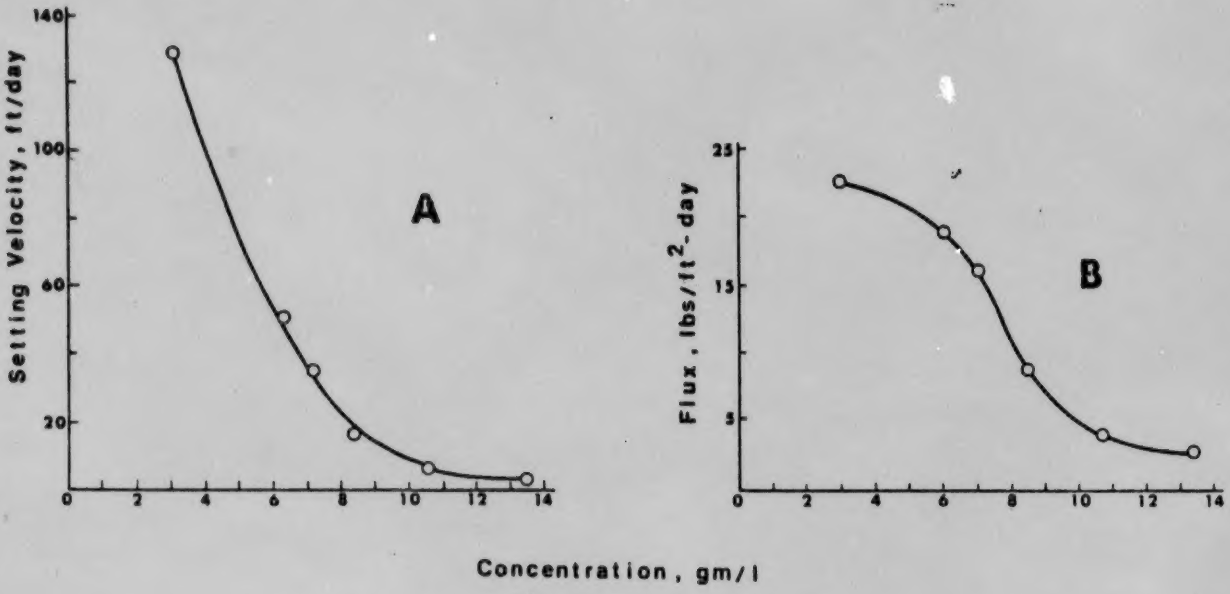


FIGURE 13 ISV and Settling Flux vs. Concentration

velocity of the sludge increases due to reflocculation.

2. Calculation and plotting procedures

   a. Experimental interface settling velocities are subsequently plotted as a function of sludge solids concentration (Figure 13A)

   b. Since the settling flux is defined as the product of the solids concentration and the corresponding initial interface settling velocity, the settling flux curve (Figure 13B) is developed by plotting the product of the ordinate an abscissa values of the settling velocity vs. solids concentration curve as a function of solids concentration. The resultant batch settling flux curve serves as the basic working diagram for all design and operational control procedures.

3. It must be emphasized that selection of a representative sample is of paramount importance in developing the batch settling flux curve. For design purposes, a representative sludge may be obtained either from an existing facility that is operated under conditions that are similar to those specified for the plant which is being designed or from a pilot plant when no representative sludge is otherwise available. Because sludge settling characteristics change with solids residence time, seasonal temperature, and biomass population shifts, among other factors, all such factors must be considered when selecting a representative sludge.

   When analyzing the operational state and making operations control decisions for an existing activated sludge system, a representative sludge is available at all times. The question that remains, however, is "how frequently should the gravitational settling velocity tests be performed to ensure that the settling flux curve employed for analysis is, indeed, current and applicable?" No specific answer can be given at this time, since changes in sludge settling characteristics are systems specific. Changes can occur on a weekly basis and perhaps even daily or hourly.

4. Apparatus - Batch system

   a. To obtain laboratory interface settling velocities that are representative of settling velocities that occur in prototype secondary clarifiers the following conditions outlined by Vesilind (9) must be observed when constructing the requisite laboratory equipment and when conducting the tests themselves:

      1. The settling column diameter should be as large as possible--8 inches is a practical compromise.

2. The initial liquid depth should be the same as the depth of the prototype thickener. When this is impracticable, 3 feet should be considered as the minimum.

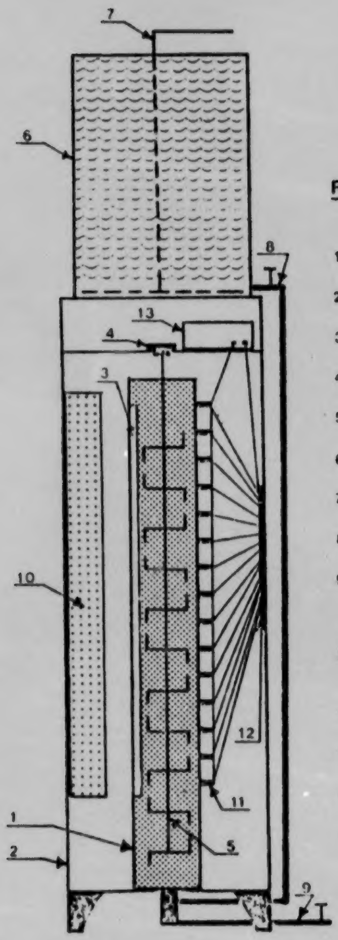
3. The sludge slurry should be slowly introducted into the column through the bottom to minimize turbulence and the attendant shearing of floc.

4. The sample should be slowly stirred throughout the test using a "rake" type of mechanism. Reasonable rotational speeds range from 0.5 to 1.0 RPM.

5. The temperature of the sample must be maintained constant throughout the test; preferably within a 3° centigrade range.

b. An analog/digital solids-liquid interface settling monitor developed by George (5) and shown in Figure 14 meets the above criteria. It provides for the automatic off-line measurement of the batch settling properties of bio-solids. Liquid interface could be monitored manually.

c. An alternative approach for determining interface settling velocities requires the use of the



Required Equipment

1. Settling Column
2. Wood Frame
3. Yardstick
4. One RPM Motor
5. Stirring Rake
6. Sludge Reservoir
7. Air Hose
8. Inlet Pipe And Valve
9. Drain Pipe And Valve

Auxiliary Equipment

10. Light Source
11. Photocells
12. Wiring Harness
13. Strip Chart Recorder

FIGURE 14 Schematic of Test Batch Settling Column

fluidization apparatus shown in Figure 15. The procedure for developing settling flux curves using this apparatus is: (1) charge the column with a specific mass of sludge; (2) fill the storage vessel with sludge supernatant; (3) introduce flow of supernatant through the bottom of the column at a predetermined flow rate (V_s); (4) allow the teeter bed to attain a steady-state height; (5) collect a sample of solids from the column through a sampling port; (6) determine the suspended solids concentration of the sample (c); (7) increase the flow rate of supernatant to a new V_s; (8) repeat procedures (4) through (7); and (9) establish settling flux curve from V_s vs. c curve; it is to be noted that this approach is much less manpower intensive than is the batch approach described in paragraph (b).

II. SYSTEM DESIGN

A. Interactions among the various components of wastewater treatment systems must be recognized if cost effective designs are to be achieved. In most previous designs of the aeration basin/clarifier system, the two units have been treated as distinct entities that have no interactions. Dick (2) has illustrated the interactions between the two processes and has developed a procedure for clarifier design that accounts for these interactions. This section will extend his work and develop a procedure for evaluating the economic trade-offs between alternative activated sludge system designs.

B. Design Basis/Aerator

1. Solids residence time

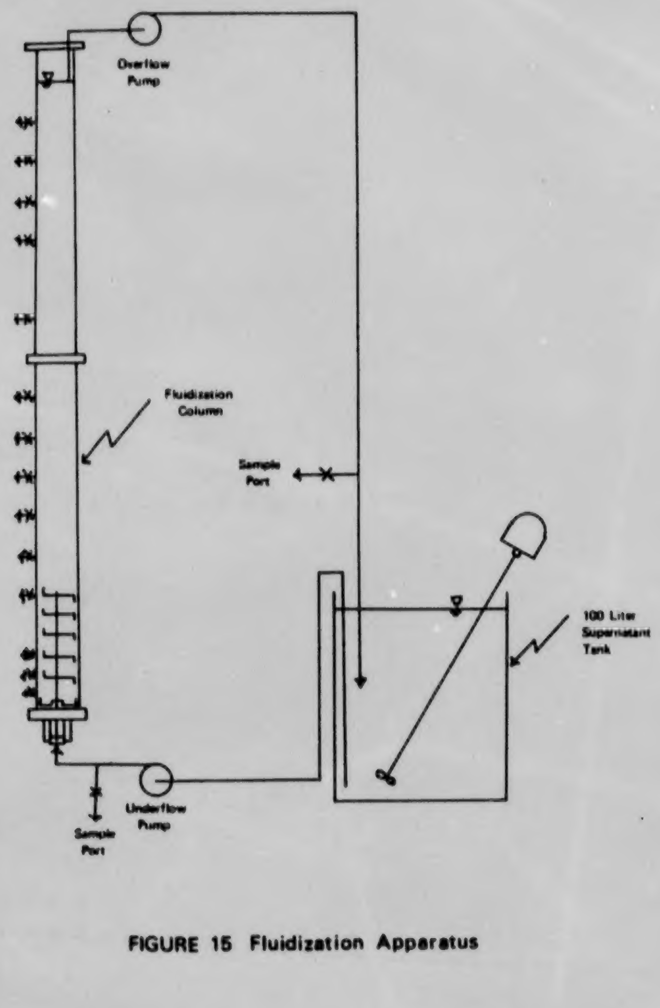


FIGURE 15 Fluidization Apparatus

a. Design of the aeration basin of the activated sludge process should be based on effluent quality criteria. When selecting a mean solids residence time (SRT, θ_c) consideration must be given to: (1) soluble carbonaceous matter in the effluent; (2) particulate carbonaceous matter in the effluent; (3) thickening characteristics of the biological solids; (4) nutrient control alternatives; and (5) process stability.

b. If removal of carbonaceous BOD is the primary objective in selecting the design SRT value, then one must consider the variability of the first three quality criteria with respect to SRT. Figures 16, 17 and 18 are examples of such relationships. These were established by Stensel and Shell (6) and Bisogni and Lawrence (7) respectively. Only the relationship which describes the soluble carbonaceous matter in the effluent under steady-state conditions given in Figure 16, is generally applicable for domestic wastewater. The relationships which describe thickening and clarification characteristics, given in Figures 17 and 18 are not generally applicable. These are system specific and should, therefore, be established for each system that is to be investigated.

c. Upon having selected an appropriate value for solids residence time, the bio-oxidation model of Lawrence and McCarty (8), which defines the mean SRT in terms of reactor design parameters, (θ, C_o), influent conditions (S_o), and microbial characteristics (Y, k_d),

$$C_o = \frac{Y\,(S_o - S)}{1 + k_d\theta_c}\;\frac{\theta_c}{\theta}$$

can be employed for establishing a design value for the aeration basin MLSS, C_o. It is to be noted that C_o varies inversely with values assumed or selected for the hydraulic residence time, θ: i.e. for greater assumed design values of θ, the required MLSS, C_o, decreases proportionately. Equation 4 applies only for the case of a completely mixed aeration chamber. If a system is to be designed for a plug flow hydraulic regime, then the design equation must be modified accordingly. Lawrence and McCarty (8) should be consulted in this regard.

2. Hydraulic residence time

a. Although the foregoing consideration showed that a broad range of hydraulic

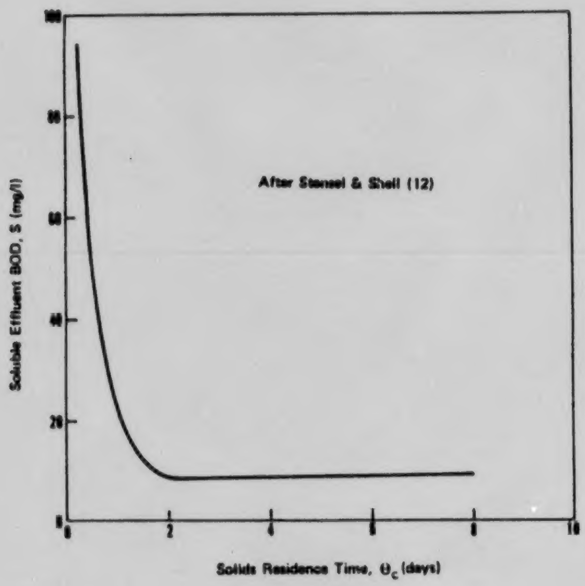


Figure 16 Soluble Effluent BOD vs. Solids Residence Time

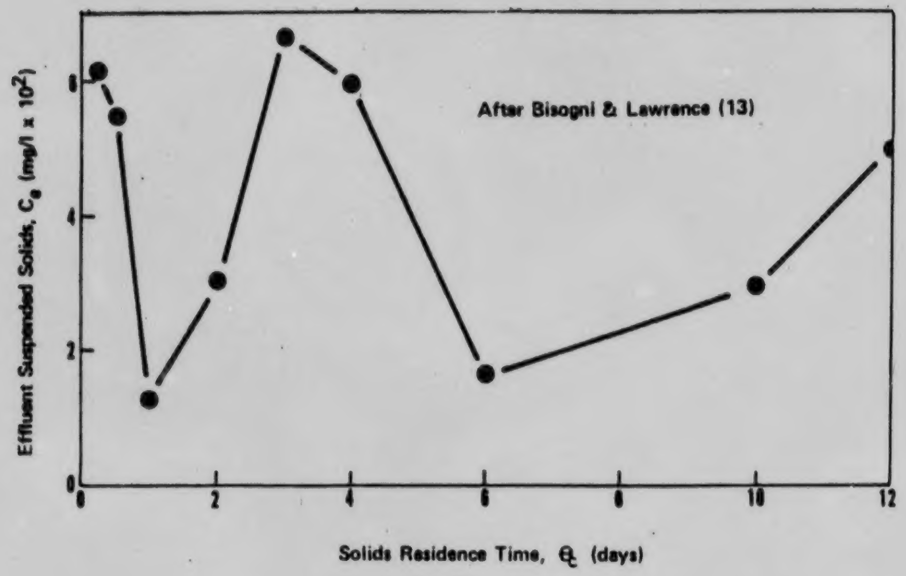


FIGURE 17 Effluent Suspended Solids vs. Solids Residence Time

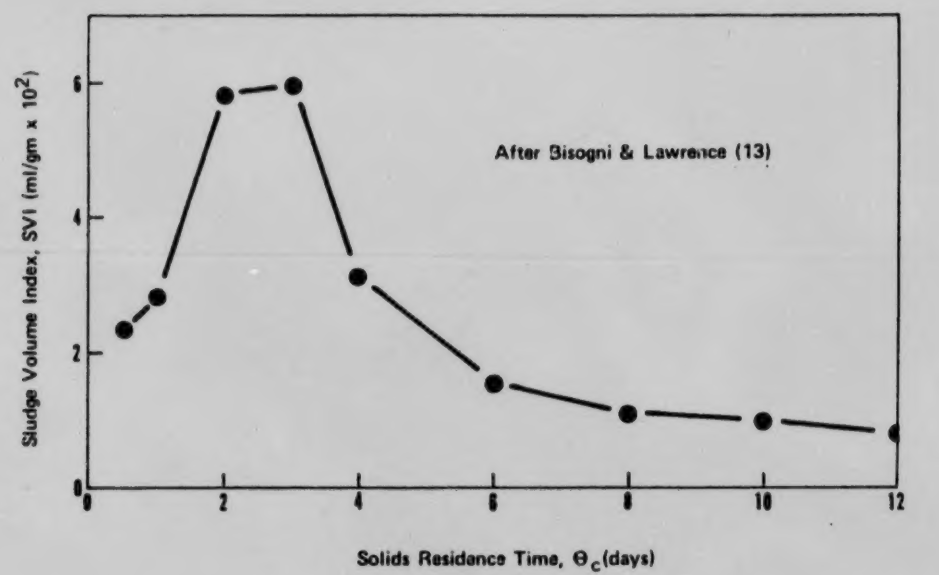


FIGURE 18 SVI vs. Solids Residence Time

residence times can be employed while meeting the solids residence time design criterion, certain constraints must, on occasion be imposed. Factors such as (1) process resilience to the imposition of shock loads, (2) kinetics of degradation of large polymeric molecules, (3) maximum aeration capacity per unit volume, (4) maximum agitation intensity per unit column, (5) process stability, and (6) concentration of mobile ciliates must be considered when establishing constraints for hydraulic residence time. The first five must be considered when establishing a lower level constraint on the hydraulic residence time while the last must be considered when establishing an upper limit on 0.

b. It is often necessary to establish a minimum hydraulic residence time requirement when designing an activated sludge system for treating industrial wastewaters. This is usually done for the purpose of accommodating shock loading inputs and providing for the degradation of large polymeric molecules. Usually, however, these two criteria are not as important when designing municipal wastewater treatment facilities. Nonetheless, the criteria regarding aeration capacity and agitation intensity must be considered in the design of municipal systems, because the quantity of air that must be supplied per unit of aeration chamber volume is larger for smaller design hydraulic residence times. The constraint regarding aeration capacity is simply a physical constraint with respect to the maximum number of diffusers or surface aerators that can be installed per unit volume of aeration chamber. Conversely, the constraint regarding agitation intensity is a performance constraint. That is for smaller hydraulic residence times the agitation intensity in the aeration chamber is greater. Since it has been shown that excessive shear rates in the aerator tend to break up the biological floc resulting in a degraded quality effluent, a lower limit on the hydraulic residence time must be established to ensure that a high quality effluent is attained.

c. The last factor that must be considered in establishing feasible hydraulic residence times is the concentration of mobile ciliates contained in the bio-solids. Pitman (9) determined that the quality of the effluent of an activated sludge plant is materially affected by the concentration of mobile ciliates and showed that the best quality effluent can be attained when the concentration of mobile ciliates is low and the concentration of crawling and attached ciliates is high. Since Pitman's studies established that these conditions are favored by long solids residence times and short hydraulic residence times, consideration should be given to the population distribution of ciliates when establishing constraints on both θ_c and θ.

C. Design Basis/Clarifier

1. Five alternative equations can be employed for sizing the secondary clarifier of an activated sludge process. These are listed in Table 1. The first of the equations listed is the simplest and, therefore, the most convenient to use. It coordinates well with the state point concept developed earlier.

2. Once a design hydraulic residence time has been selected, thereby fixing an operational MLSS value, the clarifier can be sized by assuming a value for G_0 and solving the equation for the required surface area. It is to be noted that one establishes a design state point for the system by assuming a G_0. This has the coordinates (C_0, G_0). One can then draw a recycle rate operating line which passes through the state point and is tangent to the settling flux curve as shown in Figure 9 (critically loaded case). The required minimum recycle flow rate is then calculated as the product of the clarifier surface area, A, and the recycle rate bulk transport velocity term, u.

3. One must recognize that only those values assumed for G_0 that lie beneath the envelope of the settling flux curve at the specified C_0 (MLSS) will result in technically feasible designs for the clarifier. The greater the value assumed for G_0, the smaller is the required size of the clarifier, A, and the larger is the minimum required recycle flow rate, R. It is apparent, therefore, that an economic trade-off exists between clarifier size and recycle pumping capacity for different assumed values of G_0. Values assumed for G_0 are however, subject to several constraints as discussed below.

TABLE 1: Clarifier Design Equations

$$A = (C_0 * Q_i)/G_0 \qquad (5)$$

$$A = (C_0 * R)/(G_L - G_0) \qquad (6)$$

$$A = C_0 (Q_i + R)/G_L \qquad (7)$$

$$A = C_0 (Q_i + R)/C_u * u) \qquad (8)$$

$$A = R/u \qquad (9)$$

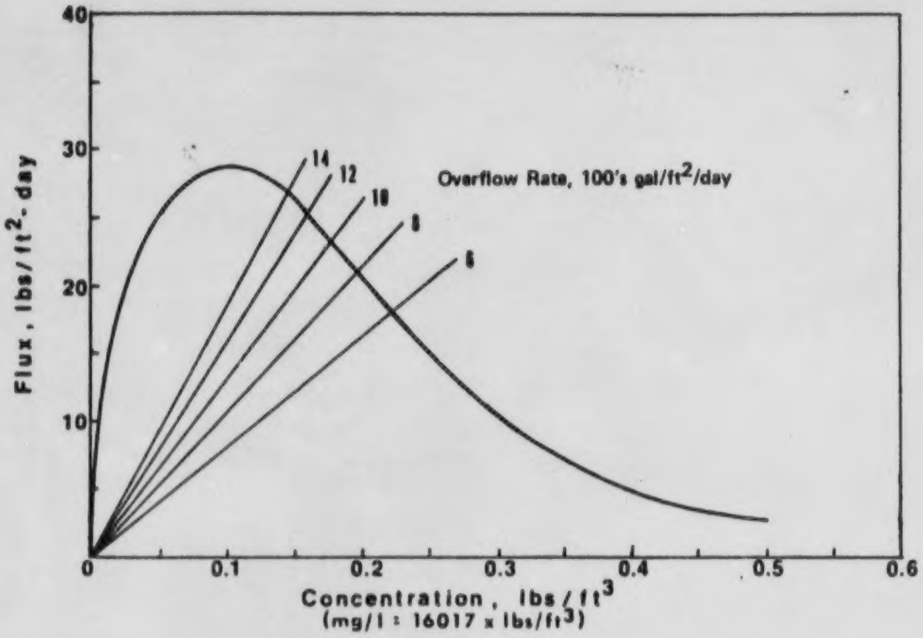


FIGURE 19 Overflow Rate Design Constraints

4. Clarification constraint

   a. Design of secondary clarifiers must be based on clarification as well as thickening critieria. A clarification constraint is established by arbitrarily selecting a peak or maximum overflow rate, (Q_i/A), that is consistent with satisfactory operating experience. Even though the overflow rate is actually equivalent to $(Q_i-W)/A$, it is approximately equal to Q_i/A, as noted above.

   b. Figure 19 shows five clarification or overflow rate constraints ranging from 600 to 1400 gal./ft.²/day. Technically feasible values that one could assume for G_o, therefore, can only lie within the envelope described at the upper bound by the clarification constraint and the settling flux curve.

   c. Recent studies by Pflanz (16) and Agnew (17), were conducted to define clarification efficiencies in the activated sludge system. An analysis of the data presented by Pflanz yielded the following relation with respect to overflow suspended solids:

$$C_e = 4.5 + 1.27 \times 10^{-5} (C_o \times Q_i/A) \quad (10)$$

$$C_e = 18.2 + 0.0136 (Q_i/A) - 0.0033 C_o \quad (11)$$

   Both of these correlations show suspended solids in the clarifier effluent to be a function of the overflow rate as well as the mixed liquor suspended solids concentration, C_o. It is interesting to note, however, that while the Pflanz expression predicts higher effluent suspended solids levels, C_e, for higher mixed liquor suspended solids concentrations, C_o, the Agnew function predicts the precise converse, i.e., decreasing effluent suspended solids levels for increasing C_o's. This anomaly in experimental observation cannot be resolved at this time due to the lack of an adequate data base. Nevertheless, the two functions can serve as useful empirical alternatives to the clarification constraint described above.

   d. Figures 20 and 21 show clarification constraints developed for various desired effluent suspended solids levels, C_e, using the Pflanz (10) and Agnew (11) expressions, respectively. The constraints developed using the Pflanz function appear as horizontal lines. This is because the Pflanz constraint on solids surface feed, G_o, for a specified effluent suspended solids level.

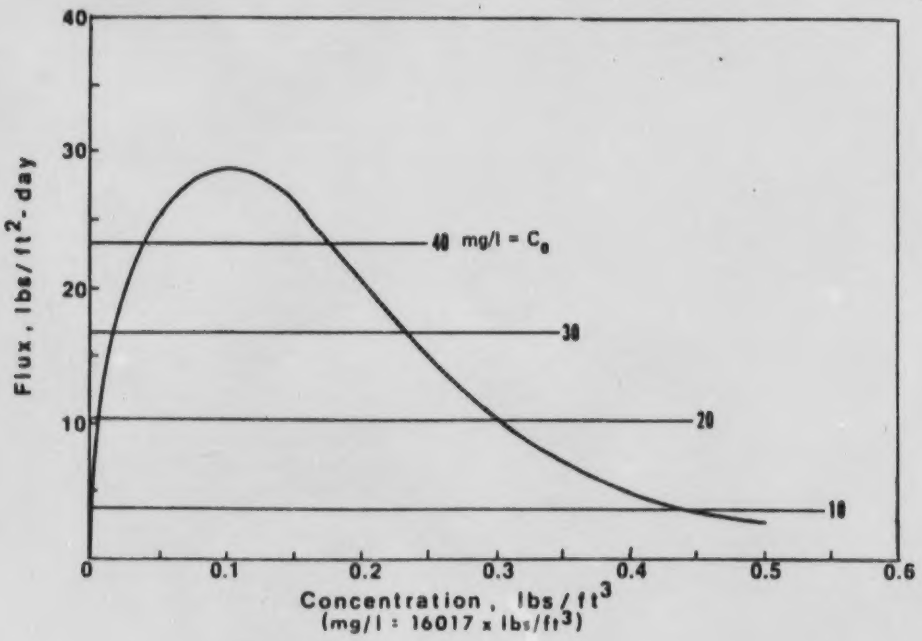


FIGURE 20 Overflow Rate Design Constraints After Pflanz (16)

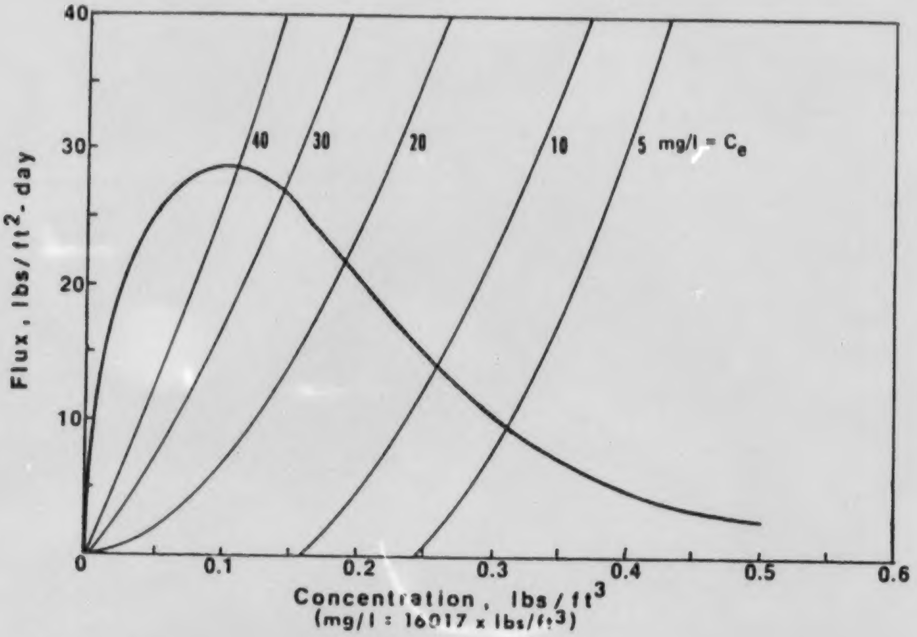


FIGURE 21 Overflow Rate Design Constraints After Agnew (17)

5. Clarifier underflow concentration constraint.

   a. It is often desirable to place a lower bound on the concentration of sludge solids that are wasted from the underflow of the secondary clarifier. In the case of the conventional activated sludge system this is usually done when no special provision is to be made for independent sludge thickening prior to digestion or some other form of sludge processing. For extended air activated sludge treatment systems where the waste sludge is commonly discharged directly to sand drying beds, it is also desirable to place a lower constraint on the concentration of solids in the underflow of the clarifier.

   b. Such a constraint is established by constructing a linear trace which is tangent to the settling flux curve intersecting the x-axis at the minimum desired sludge solids concentration. Three examples of such constraints are shown in Figure 22 for the cases in which the minimum clarifier underflow suspended solids concentration is limited to 6407, 8009, and 9611 mg/l (0.4, 0.5, and 0.6 lbs/ft.^{3}, respectively).

   c. The underflow concentration constraint is an upper bound for design state points (C_o, G_o) which lie to the left of where the constraint line and the settling flux curve are tangent. For state points that lie to the right of the point of tangency, the settling flux curve itself is the upper boundary, because the underflow concentration constraint is automatically satisfied in such cases.

   d. Consideration should also be given to eliminate unrealistically high underflow concentrations from the feasible design domain. This is because the compressive strength of the solid phase may preclude extremely high concentrations. This type of upper concentration constraint would form a lower bound on the feasible design domain. This type of constraint would virtually never influence the design of the least cost solution. Therefore it is not necessary to impose this constraint prior to evaluating various design alternatives. Rather, the least cost design obtained without imposing this constraint should be checked to ensure that it does not violate the upper concentration constraint.

6. Recycle rate constraint

   a. When evaluating economic trade-offs between alternative activated sludge

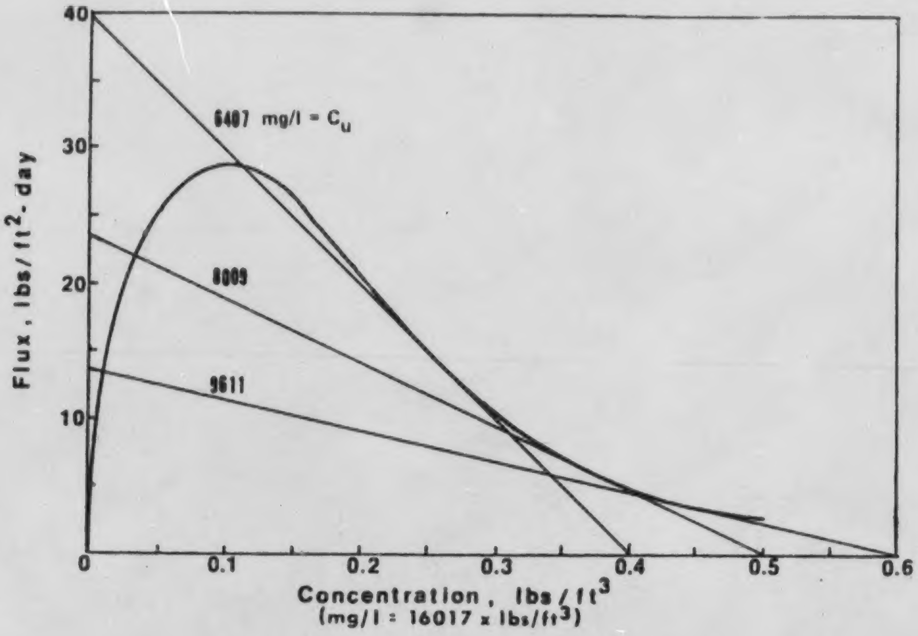


FIGURE 22 Underflow Concentration Design Constraints

system designs one occasionally arrives at an apparent least cost design for which the required recycle rate may not be realistic. That is, required recycle flow rates for the lowest cost design case can be as high as 300 to 400 percent of the influent flow rate. Cost calculations include the capital costs associated with the installation of recycle pumping. However, no consideration is given in the design procedure or the effect high recycle pumping rates have on the quality of the effluent. While no direct evidence is available, high recycle pumping rates probably degrade the quality of the effluent by increasing turbulence and therefore decreasing clarification efficiencies in the secondary clarifier. Consequently, it may be desirable to impose recycle pumping rate constraints on the feasible design domain.

b. Two recycle flow rate constraints, 50 and 100 percent of the influent flow rate, are shown in Figure 23 for illustration purposes only. This is not to imply that the recycle rate should be limited to these levels. Constraint levels will become apparent when the clarification process becomes better understood. These recycle rate constraints were constructed by evaluating the following inequality employing a trail and error procedure.

$$\frac{u}{G_o -} \ll \frac{(R/Q_I)}{C_o} \qquad (12)$$

This constraint, as well as the underflow constraint, is a function of the settling flux curve. If a recycle flow rate constraint is to be imposed, it is an upper bound for the feasible design domain.

c. Because considerable effort is required to develop a recycle rate constraint, it is desirable to first evaluate the design alternatives without the recycle rate constraint. If the resulting lowest cost design requires an unacceptably high recycle pumping rate, the design should be repeated with a recycle rate constraint included.

7. Application of clarifier constraints

a. A clarification constraint must be considered in each design. If this were the only constraint applied, the feasible design domain would consist of the shaded area shown in Figure 24 (Q_I/A = 800 gal./ft.^{2}/day). The alternative design operational points that are

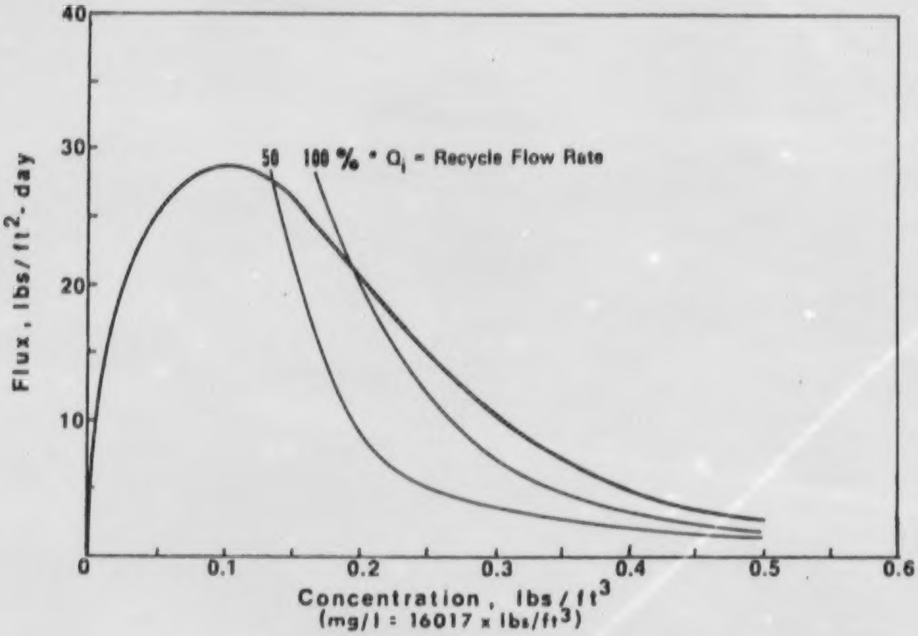


FIGURE 23 Recycle Flow Rate Design Constraints

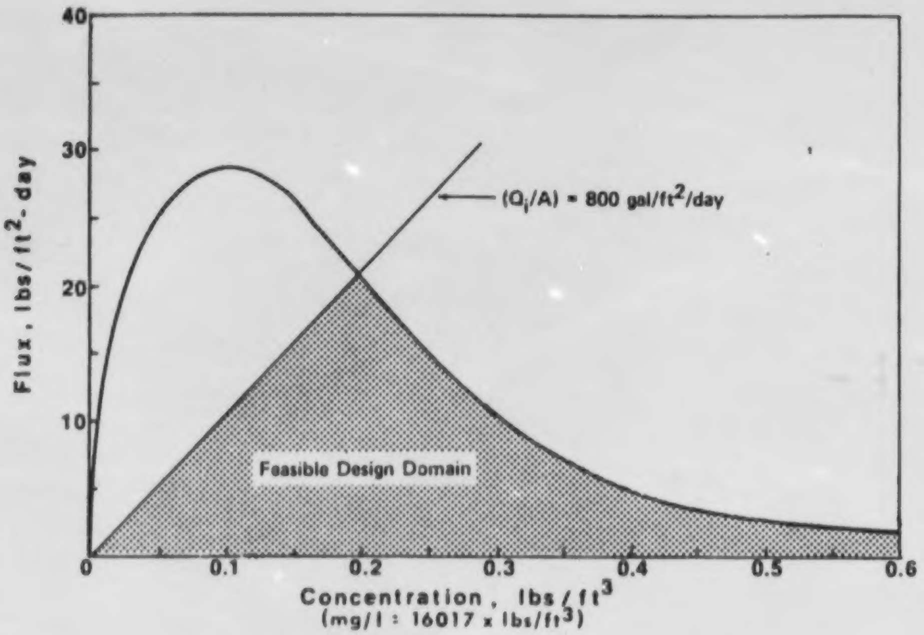


FIGURE 24 Feasible Design Domain With Clarification Constraints Only

described by the coordinates (C_0, G_0) must lie within the shaded region. All alternative designs resulting from assumed operational points that lie outside the shaded area would either violate the clarification criterion or fail due to insufficient thickening capacity.

b. If analysis of the feasible alternative designs showed that the least cost solution required a recycle flow rate that was unacceptably high, one would superimpose a recycle rate constraint as shown in Figure 25 for the case in which the recycle rate was limited to 100 percent of the influent flow rate. The feasible design domain is again shown by the shaded region.

c. If, in addition to a clarification constraint, certain process consideration dictated the imposition of an underflow concentration constraint at 0.5 lbs/ft^3 (8009 mg/l), feasible design domain would consist of the shaded area shown in future 26. As before, if it were also necessary to impose a recycle rate constraint the feasible design domain would decrease in size to that shown in Figure 27.

D. Illustrative Design Example

1. The design methodology presented above can best be illustrated by use of a comprehensive design example. For this example it has been assumed that complete mixed activated sludge treatment plant is to be designed for an average flow of 10.0 MGD and a BOD_u of 300 mg/l in the primary clarified wastewater. Based on an analysis of the functional relationships shown in Figures 17, 18, and 19, a mean solids residence time of 6 days is to be employed for the design. All cost calculations were based on cost relationships established by Patterson Banker (12). Other salient design parameters are tabulated in Table 2.

2. Assuming that the expected settling flux curve for the biological sludge is as shown in Figure 28, and assuming an overflow rate constraint of 800 gal./ft.^{2}/day, the feasible design domain is described by the shaded region. It is assumed, further, that no underflow concentration constraint need be imposed in this case.

3. As indicated above a spectrum of clarifier size/recycle flow rate design combinations is feasible at each specified hydraulic residence time (i.e., specified comcentration of mixed liquor suspended solids). The relative magnitude of the values determined for clarifier size and recycle flow rate depend on the value assumed for G_0: Larger G_0's yield smaller values for required recycle flow rate. Since this is the case, one must establish which of the

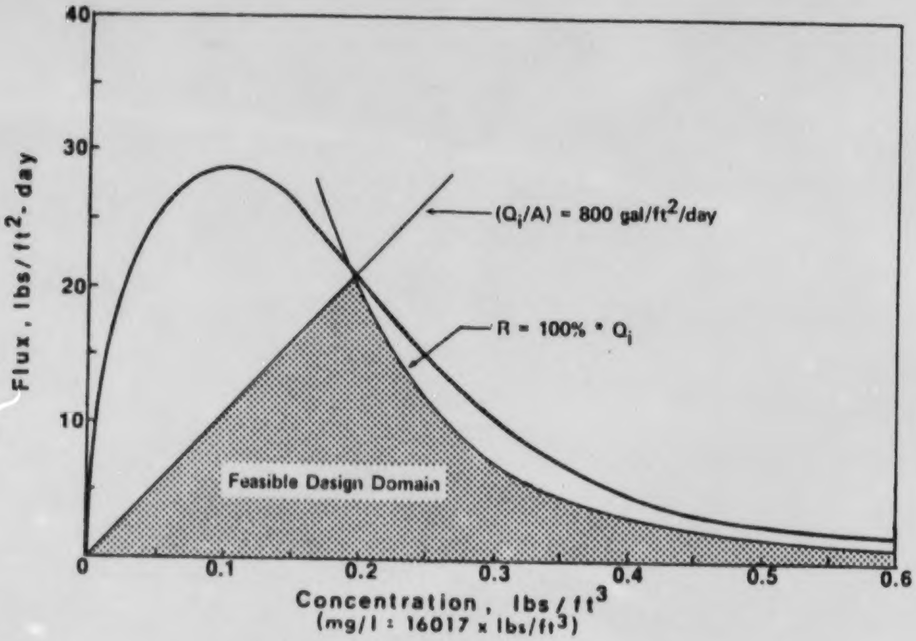


FIGURE 25 Feasible Design Domain With Clarification and Recycle Rate Constraints

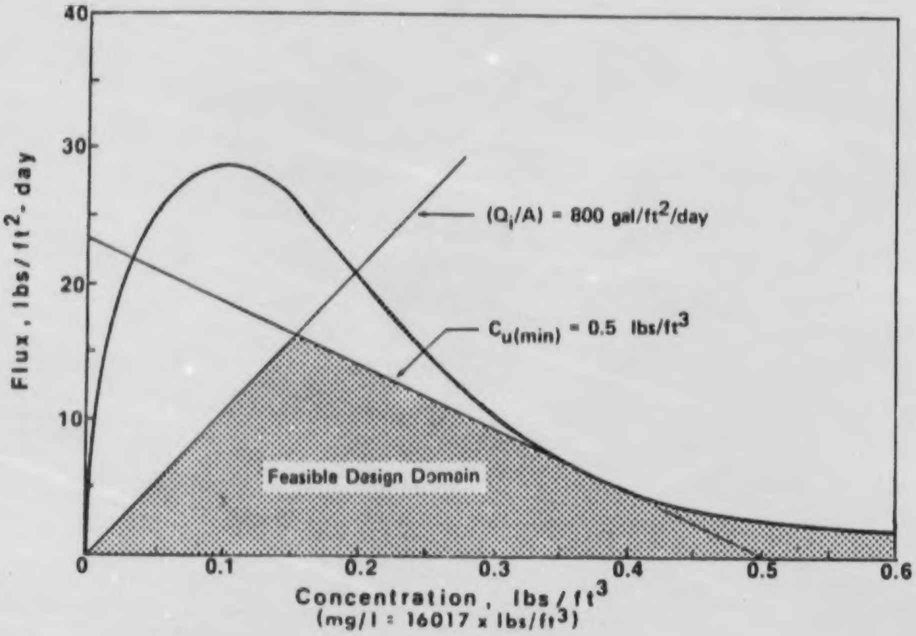


FIGURE 26 Feasible Design Domain With Clarification and Underflow Concentration Constraints

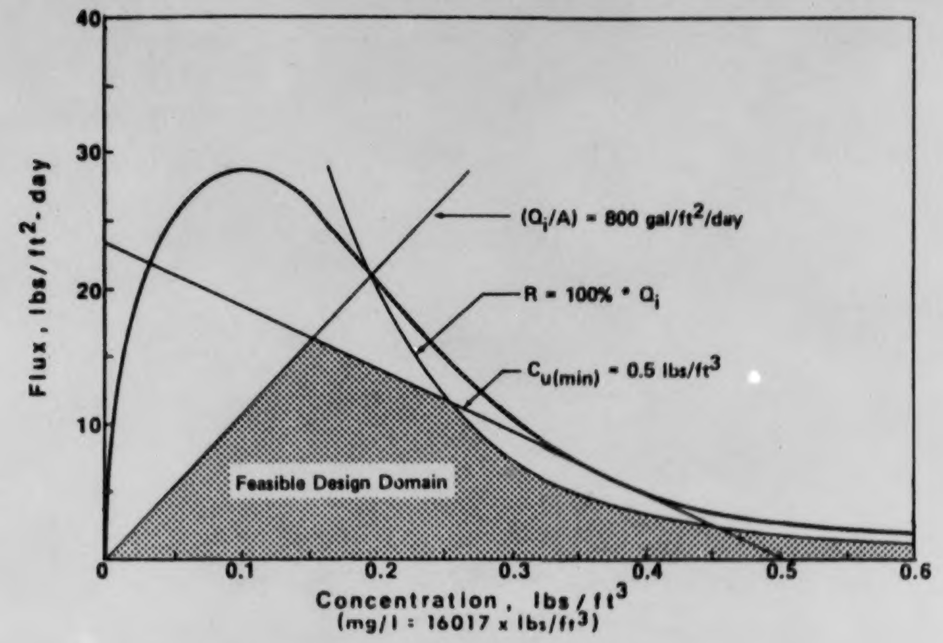


FIGURE 27 Feasible Design Domain With Clarification, Recycle Rate and Underflow Concentration Constraints

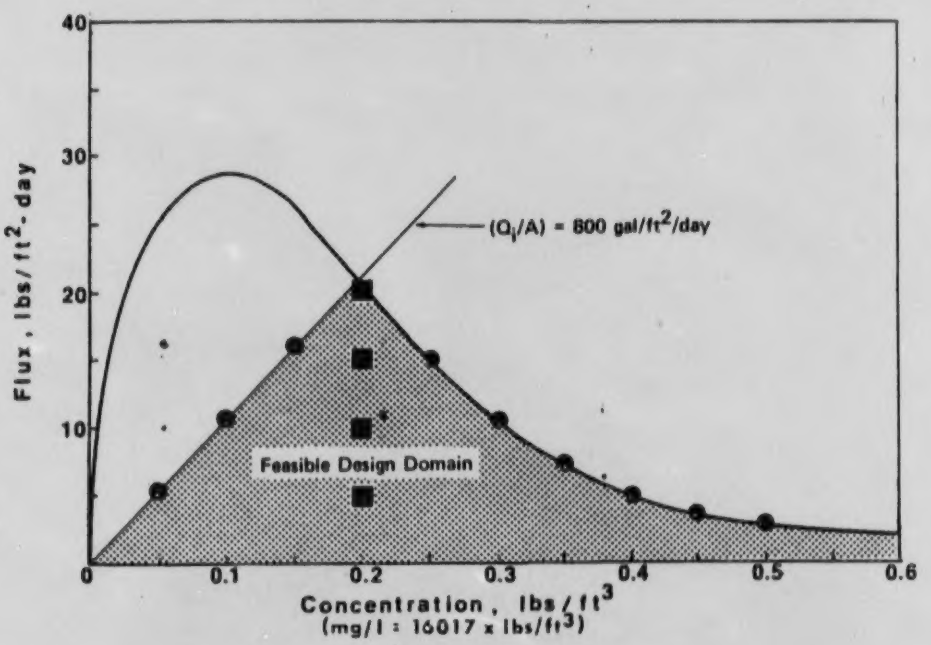


FIGURE 28 Feasible Design Domain for Example Design Problem

Influent Parameters

Q_i = 10.0 MGD (average influent flow rate)

S_o = 300 mg/l BOD_u

Effluent Parameters

$S = \leq 8$ mg/l BOD_u (soluble)

Biologic Parameters

θ_c = 6 days (design mean solids residence time)

Y = 0.5 mg vss/mg BOD_u (true yield coefficient)

k_d = 0.06 day $^{-1}$ (biomass decay rate)

MLVSS = 0.8 MLSS

Constraints

Q_i/A = 800 gal/ft^2/day (average flow basis; provides for peak flows)

Aerator mixing: Minimum of 3 cfm per foot of chamber length

Aeration capacity: Install 150% of minimum required capacity

Recycle pumping capacity: Install 150% of minimum required capacity.

Physical Parameters

Hydraulic regime: Complete mix

Oxygen transfer efficiency: 8%

Cost Parameters

Interest rate = 6% per annum

Depreciation period = 25 years

Power costs = 1.48¢/kwh

[1]Operations labor costs = $6.92/man-hour

[1]Maintenance labor costs = $6.89/man-hour

[2]Cost index: 1 January 1976 dollars

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[1] Ref: Joseph W. Larson, Superintendent of Coldwater Creek Wastewater Treatment Plant Sanitary Treatment Plant, Metropolitan Sanitary District, Annual Report 1975-76, St. Louis, MO.

[2] Means Construction Cost Indexes, 2, 1 (1976).

TABLE 2 Design Parameter Values

combinations give the least combined cost for each specified hydraulic residence time.

4. To establish the trade-off relationships for the critical case of θ equal to 6 hours (C_o = 0.2 lbs/ft^3, 3203 mg/l, cost comparison calculations were conducted for five selected values of G_o. The design operating points with coordinates (C_o, G_o) are shown in Figure 28 as solid squares while the associated costs for the clarifier/recycle system are recorded in Table 3. Analysis of the total annual costs shows that the cost decreased for larger selected values of G_o up to 20.7 lbs./ft^2/day, although the cost relationship is insensitive for G_o values ranging from 15 to 20.7 lbs/ft^2/day. For this hydraulic residence time (θ = 6 hours), therefore, the least cost solution was obtained for the case in which the design state point was located at the upper boundary of the feasible design domain. Moreover, for all other aerator hydraulic residence time alternatives evaluated for this example, the least cost solution occurred at the upper boundary of the design domain.

5. Nevertheless, it is extremely important that one recognizes that the least cost solution does not a priori lie at the upper boundary of the design domain; it can lie anywhere within the domain. At a certain θ the location of the design state point for the least cost solution for the clarifier/recycle pumping system depends on the specifics of the system design and the unit cost relationships.

6. Annual costs calculated for the aeration basin/clarifier system for assumed hydraulic residence times ranging from 2.41 to 24.1 hours are recorded in Table 4. At each hydraulic residence time for which costs were calculated the least cost design state points are shown as solid circles in Figure 28. These are located at the upper bound as established earlier.

Variable	G_o (lbs./ft^{2}day)				
	5	10	15	20	20.7
	*** Design Values ***				
A (ft^2)	53,475	26,738	17,825	13,369	12,916
u (ft/day)	8.4	26.4	52.5	98.7	115.3
R (MGD)	3.36	5.28	7.00	9.86	11.13
	*** Clarifier Annual Costs ($) ***				
Capital Amortization	62,848	35,497	25,023	20,367	19,785
Operating Labor	19,376	12,802	9,688	7,958	7,612
Maintenance Labor	11,024	6,890	5,236	4,478	4,134
Material	8,480	4,909	3,571	2,827	2,752
TOTAL	101,728	60,098	43,518	35,630	34,283
	*** Recycle Pumping Annual Costs ($) ***				
Capital Amortization	8,496	11,406	13,966	17,458	18,221
Operating Labor	3,667	4,083	4,360	4,844	5,052
Maintenance Labor	3,376	3,513	3,652	3,996	4,203
Power	2,976	4,463	5,504	7,587	7,736
Other	922	1,175	1,710	2,529	2,540
TOTAL	19,437	24,640	29,192	36,414	37,752
	*** Total Annual Costs ***				
Dollars	121,165	84,738	72,710	72,044	72,035
Cents/1000 gal.	3.32	2.32	1.99	1.97	1.97

TABLE 3 Least Cost Design Analysis For A Specific Hydraulic Residence Time

	Hydraulic Residence Time (θ, hrs.)									
	24.12	12.06	8.04	6.03	4.82	4.02	3.45	3.02	2.68	2.41
*** Design Values ***										
C_o (#/ft^3)	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
C_o (mg/l)	801	1,602	2,403	3,203	4,005	4,806	5,607	6,407	7,208	8,009
A (ft^2)	12,500	12,500	12,500	12,916	22,281	38,938	64,988	113,779	171,886	267,380
u (ft/day)	6.37	20.09	47.2	115.26	100.0	78.52	56.6	39.8	20.09	6.37
R (MGD)	0.595	1.88	4.41	11.1	16.7	22.9	27.5	33.9	25.8	12.7
V (MG)	10.05	5.02	3.35	2.51	2.01	1.67	1.44	1.26	1.12	1.01
Air Required (cfm)	8,957	5,808	5,808	5,808	5,808	5,808	5,808	5,808	5,808	5,808
*** Aeration Basin & Aerator Annual Costs ***										
Basin Capital Amortization	151,291	67,509	48,266	36,063	30,274	26,206	22,138	19,791	18,618	17,445
Aerator Capital Amortization	33,716	33,168	33,168	33,168	33,168	33,168	33,168	33,168	33,168	33,168
Operating Labor	17,992	17,992	17,992	17,992	17,992	17,992	17,992	17,992	17,992	17,992
Maintenance Labor	10,335	10,335	10,335	10,335	10,335	10,335	10,335	10,335	10,335	10,335
Power	52,073	52,073	52,073	52,073	52,073	52,073	52,073	52,073	52,073	52,073
Other	8,778	8,778	8,778	8,778	8,778	8,778	8,778	8,778	8,778	8,778
TOTAL	274,185	189,855	170,612	158,409	152,620	148,552	144,484	142,137	140,964	139,791
*** Clarifier and Recycle Pumping Annual Costs ***										
Clarifier Capital Amortization	19,786	19,786	19,786	19,786	30,260	48,882	75,651	110,567	174,579	256,049
Pumping Capital Amortization	3,607	6,052	10,241	18,221	26,769	34,920	40,735	47,136	37,243	22,113
Clarifier Operating Labor	7,266	7,266	7,266	7,612	12,110	15,916	22,144	31,140	40,136	50,516
Clarifier Maintenance Labor	4,065	4,065	4,065	4,134	6,201	8,612	12,402	17,914	22,048	27,560
Pumping Operator Labor	3,128	3,391	3,944	5,052	6,020	7,612	8,304	8,966	7,612	5,536
Pumping Maintenance Labor	2,549	2,825	3,307	4,203	4,961	5,994	6,545	7,579	6,270	4,616
Clarifier Material	2,700	2,700	2,700	2,752	4,315	6,695	9,819	14,878	20,829	28,268
Pumping Power	1,042	2,083	4,017	7,736	11,902	16,366	18,597	25,293	17,100	9,075
Pumping Other	461	640	1,175	2,540	3,868	5,505	6,100	8,183	5,700	2,926
TOTAL	44,604	48,808	56,501	72,035	106,406	150,502	200,297	271,686	331,517	406,709
*** Total Annual Costs ***										
Dollars	318,789	238,663	227,113	230,444	259,026	299,054	344,781	413,823	472,481	546,500
Cents/1000 gal.	8.73	6.54	6.22	6.33	7.09	8.19	9.44	11.34	12.94	14.97

TABLE 4 Least Cost Design Analysis

7. Analysis of the annual costs calculated for the aeration basin and aerator and for the clarifier and associated recycle pumping, plotted in Figure 29, shows that the least cost solution was obtained for a hydraulic residence time of approximately 8 hours. One can observe that the total cost function is extremely sensitive for low hydraulic residence times and is considerably less sensitive for higher hydraulic residence times. This is primarily due to the clarifier and recycle pumping cost function.

8. The required recycle flow rate was 44.1 percent of the influent flow for the least cost solution. Since this is commensurate with operations practices that are employed at treatment plants producing high quality effluents, it was not necessary to apply a more stringent recycle rate constraint. Nonetheless, had the least cost solution required an unrealistically high recycle flow rate, then a recycle flow constraint should have been applied. This would have increased the total annual costs for small hydraulic residence times, thereby shifting the least cost solution toward higher O's.

9. No underflow concentration constraint was applied for this example. If one had been applied, however, it also would have served to increase the total annual costs for small hydraulic residence times and would have shifted the least cost solution toward higher O's.

10. It is noteworthy, furthermore, that one could extend the methodology presented herein to evaluate the economic alternatives for the entire aeration basin/clarifier/sludge processing system. This would be achieved by including sludge processing costs in the least cost calculations an by iteratively applying a spectrum of feasible underflow concentration constraints.

III. OPERATIONAL STATE ANALYSIS AND CONTROL

A. Operations Objectives

1. As indicated in the introductory paragraphs, the batch settling approach can be used by operations personnel to monitor the operational state of an activated sludge system. Bio-solids inventory control decisions can subsequently be made in response to both short-term (diurnal) and long-term (seasonal) changes in the plant influent and system operational conditions. The approach is to be employed in conjunction with a suitable SRT solids wasting control strategy such as those proposed by Garrett (13) for direct wasting from the aerator or by Zaander and Johnson (14) and Walker (15) for systems in

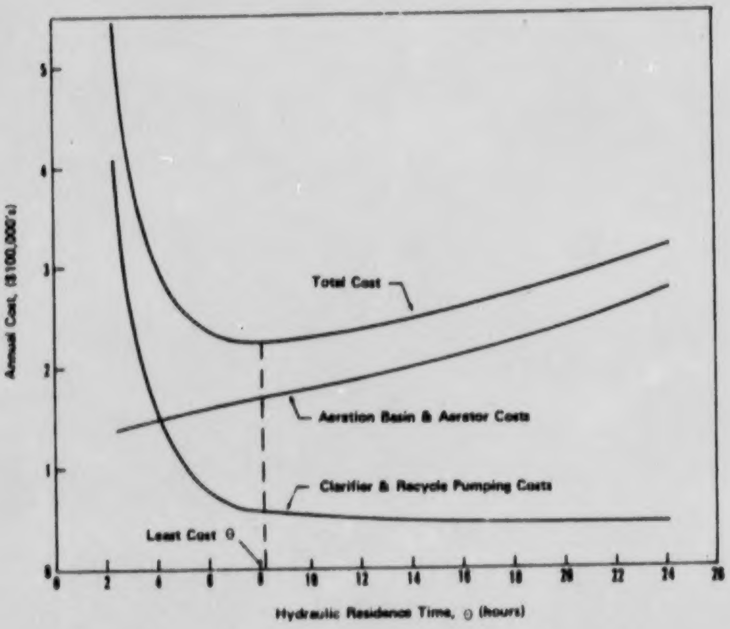

FIGURE 29 Costs for Activated Sludge Treatment System

which sludge is wasted from the settler underflow. A more precise solids wasting strategy that includes the loss of suspended solids in the plant effluent, as presented by Roper and Grady (16), could also be employed. Any of these can be used to effectively control an activated sludge system at a desired set-point solids residence time that provides the desired performance and process stability.

2. Within the constraint of a desired solids residence time which establishes the sludge wasting program, the treatment plant operator can control only the recycle flow rate to control the bio-solids inventory in the aerator/clarifier system of a conventional activated sludge treatment plant. The objectives of recycle rate control are: (1) to prevent clarifier failure due to either thickening or clarification overload and (2) to produce a thickened sludge to minimize sludge processing and disposal costs. Within these objectives, moreover, it is desirable to minimize the recycle flow rate in order to minimize recycle pumping operating costs, hydraulic currents, and C_L' which is the driving gradient for transport of bio-solids over the weirs and into the overflow.

3. Analysis of Equation 4 shows that the concentration of mixed liquor suspended solids, C_0, varies as a function of the concentration of substrate in the influent, S_0, and the hydraulic residence time, θ, for a constant θ_c. Such variation in C_0 due to organic loading can easily be included in analytical procedure is slightly complicated. However, it is usually not necessary to consider these variations when analyzing the average changes in the state of a system, provided the mean daily value of C_0 does not change appreciably.

B. Variable Influent Flow Rate (Thickening Considerations)

1. The analysis and control procedure can best be illustrated by a comprehensive example. For this purpose it has been assumed that the plant that was designed in the preceding section (least-cost basis) is to be operated. It is recalled that the plant was designed for an average hydraulic residence time o 8.04 hours and a mean solids residence time of 6 days. The final design called for an aerator volume of 3.35 million gallons (completely mixed hydraulic regime) and an installed clarification capacity of 12.500 square feet of surface area. It has been assumed, furthermore, that the current conditions are:

   Average daily influent flow rate = 10.29 MGD

   Maximum daily influent flow rate = 12.86 MGD

   Minimum daily influent flow rate = 7.72 MGD

   Mean solids residence time (θ_c) = 5.77 days

   Recycle flow rate (R) - 4.39 MGD (42.7% of average daily influent flow)

   MLSS (C_0) = 2403 mg/l (0.15 lbs/ft^3)

   The assumed operating conditions are noted to be somewhat different than those employed for design. This was done deliberately to enable illustration of the utility and versatility of the approach.

2. Essentially all wastewater treatment plants experience both short-term (diurnal), intermediate-term (seasonal), and long-term (design period) changes in the influent flow rate. It is therefore instructive to consider how these changes affect the operational state of the plant and how a plant operator should respond to the flow changes that are imposed. For this example the base operational state is established for the case in which the plant is experiencing an average daily hydraulic rate of flow, 10.29 MGD. For this case the operational point is located as shown in Figure 30 and is described by state point (a) which has the coordinates (0.15 lbs/ft^3, 16.5 lbs./ft^2/day). The recycle rate operating line has a slope equal to 47 ft/day (labeled u_l) while the overflow rate operating line has a slope equal to 823 gal./ft^2/day (labeled (Q/A) ave.). Because the recycle rate operating line is tangent to the settling flux curve, the clarifier is critically loaded.

3. Increased hydraulic flow rates.

   a. Although influent flow rates seldom change stepwise, the flow rate has been assumed to change from the average daily flow, 10.29 MGD, to the maximum daily flow, 12.86 MGD, in a single step for illustrative purposes. The state point is seen to shift upward in Figure 30 at the same C_0 (MLSS) to state point (b) which has coordinates of (0.15 lbs./ft^3, 10.62 lbs/ft^2/day). Due to the increased flow the overflow rate operating line has an increased slope, 1028 gal./ft^2/day. As before, the wasting flow rate, w, is neglected when determining clarifier overflow rates. Since the recycle rate was not changed, the new recycle rate operating line (dashed) has simply shifted upward and has the same slope as before the step change in flow was imposed.

   b. Analysis of the new operating state shows that the clarifier is overloaded with respect to its thickening capacity

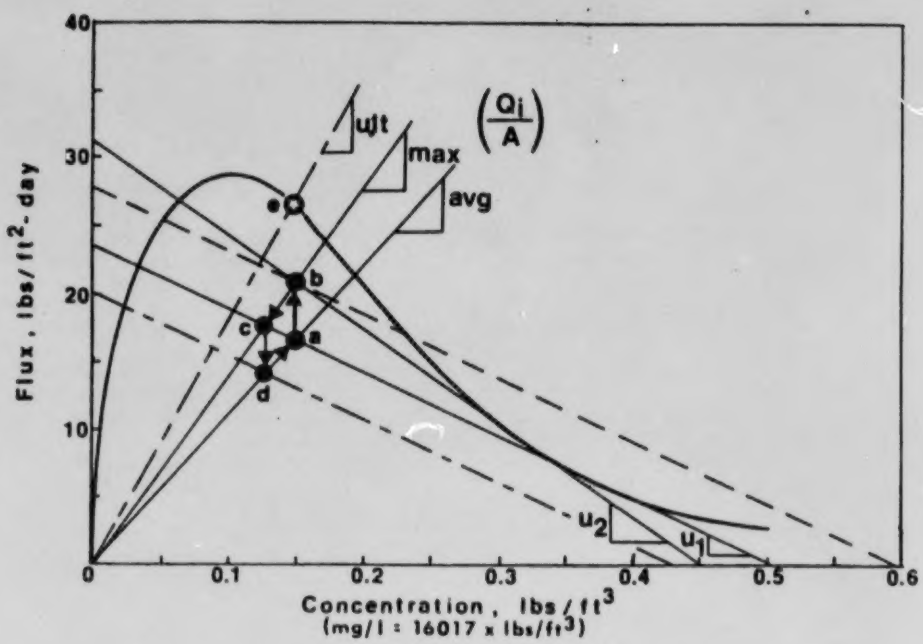

FIGURE 30 Operational States For Increased Influent Hydraulic Flow Rates

as the recycle rate operating line passes above the settling flux curve. If this condition were allowed to persist, biological solids would be transferred from the aerator and would accumulate in the clarifier. To resolve this condition, the operator could increase the recycle flow rate such that the recycle flow rate operating line has a slope equal to 69.33 ft/day (u_2). This corresponds to a recycle flow rate of 6.48 MGD or 50.4 percent of the influent flow. The resulting operating state corresponds to a critically loaded state for the clarifier. This is a stable state for which the recycle flow rate is at a minimum.

c. Conversely, if the plant operator took no control action in response to the imposed maximum daily hydraulic flow, then the clarifier's thickening capacity would be overloaded as mentioned above. The system would itself respond by transferring biological solids from the aerator to the clarifier. This would dilute out the solids in the aerator resulting in a decreased concentraton of mixed liquor suspended solids. The solids "blanket" in the clarifier would rise to accomodate the solids that were transferred. This shift in operational states is shown in Figure 30. From the overloaded state (state point b) the state point would shift down along the overflow rate operating line until it reached the location of point (c), which corresponds to a stable operational state for the aerator/clarifier system for which the recycle rate was not changed. Thereafter, no further change in the operating state of the system would be observed; i.e. no additional bio-solids would be transferred from the aerator to the clarifier.

d. To calculate the mass of solids transferred during the shift from the overloaded state to the critically loaded state (point b to point c), one would simply graphically establish the original and final concentrations of mixed liquor suspended solids, C_0, take the difference and multiply by the aerator volume. For this case the original and final C_0 values were 2403 mg/l (0.15 lbs/ft^3) and 2082 mg/l (0.13 lbs/ft^3), respectively. One can then calculate that approximately 8957 pounds of bio-solids would be transferred from the aerator to the clarifier.

e. It is also interesting to establish precisely how the clarifier would accommodate the solids. As noted previously, the solids would accumulate in the clarifier in the form of a "blanket" at a concentration equal to C_L which has a value of 6087 mg/l (0.38 lbs/ft^3) for the current operating conditions. Since 4750 pounds of bio-solids (0.38 lbs./ft^3 x 12,500 ft^3) can be stored in the clarifier per foot of clarifier depth at that concentration, it is apparent that the solids blanket would rise approximately 1.9 feet in the clarifier and then stabilize. Because clarifiers usually have 6 to 8 feet of depth available for storage of bio-solids beneath the feed point, one notes that the clarifier would not fail for the transition in operational states considered.

f. If the influent flow rate to the plant subsequently changed stepwise from the maximum value, 12.86 MGD, back to the average value, 10.29 MGD, the operational point would correspondingly shift in Figure 29 from state point (c) to state point (d) which has the coordinates (0.13 lbs/ft^3, 14.3 lbs/ft^2/day). This operating condition is one in which the clarifier is underloaded as evidenced by the recycle rate operating line (long & short dashes) which passes beneath the settling flux curve. Solids that are stored in the clarifier in the "blanket" consequently would be transferred from the clarifier back into the aerator. This would result in a shift of operational states from state point (d) to state point (a). At the latter state point the blanket in the clarifier would have been entirely dissipated.

g. Clearly, clarifiers offer considerable capacitance for accommodating the usual diurnal fluctuations in influent hydraulic flow rate. Only for certain critically located state points that are near the settling flux curve, would one expect the blanket to propagate upward in the clarifier to the extent that solids would be scoured from the blanket over the weirs and into the effluent.

4. Decreased Hydraulic Flow Rates

a. If the flow to the treatment system were to decrease, then the state point would shift downward at the same C_o (MLSS). This is illustrated in Figure 31 for the case in which the influent flow rate changed stepwise from the average, 10.29 MGD, to the daily minimum flow of 7.72 MGD (state point

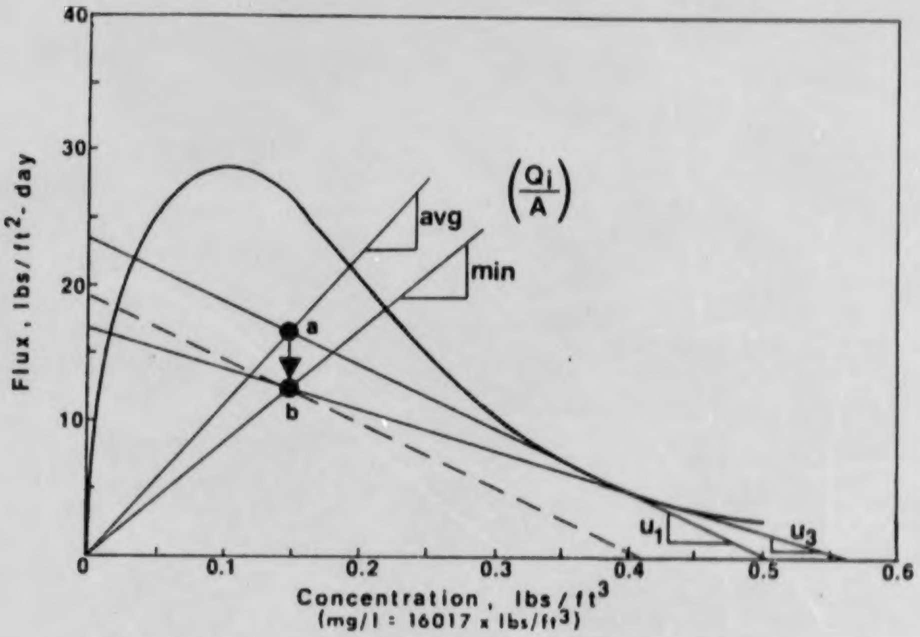

FIGURE 31. Operational States For Decreased Influent Hydraulic Flow Rates

(a) to state point (b). If the treatment plant operator did nothing in response to the change in flow, the recycle rate operating line would be positioned as shown by the dashed line. It is noted, however, that for this operational state the clarifier is underloaded. The recycle rate could accordingly be reduced to the point of critical loading; i.e., decrease the slope of the recycle rate operating line to 30.1 ft/day (u_3) which corresponds to a recycle flow rate of 2.82 MGD or 36.5 per cent of the influent flow. This control action is beneficial as it results in reduced recycle pumping operating costs, reduced turbulence in the clarifier, and a reduced C'_L which should, in turn, result in upgraded clarification efficiencies.

b. For all situations in which the clarifier is underloaded, the vast majority (95 + %) of the bio-solids are in the aerator and no significant redistribution of solids between the aerator and clarifier occurs. Accordingly, the concentration of mixed liquor suspended solids should vary only in response to changes in organic loading to the aerator, provided, of course, that a carefully controlled solids wasting procedure is employed to maintain a constant set-point solids residence time.

5. Flow Proportional Control

1. Many wastewater treatment plants are operated with flow proportional control of the recycle pumps. If this control strategy had been employed for the example discussed above, then the recycle flow rates that would have been used based on a 42.7 percent recycle ratio are 3.30, 4.39, and 5.49 MGD respectively. Comparing these with the recycle flow rates required to maintain the clarifier in a critically loaded condition one observes that for the minimum influent flow the flow proportional recycle rate was somewhat greater than required (Table 5). Conversely, the proportional recycle flow was smaller than the required recycle flow for the maximum influent flow case. For the average flow case the two compared precisely since the basis of selecting the ratio was the case of average flow and critical loading. It is apparent, therefore, that while the flow proportional recycle control strategy did not provide for the precise recycle rate required to maintain the clarifier in a critically loaded condition, it did provide a relatively good estimate of the required flow. Accordingly, one can conclude that this control strategy could be employed as an alternative approach for minimizing set-point recycle flows. It would provide for relatively stable diurnal operation of an aerator/clarifier system if the recycle ratio were properly selected.

b. If the flow proportional recycle ratio had been selected at some value greater than that determined for the average flow/critical loading case, then a different control situation would result. To illustrate, it is assumed that a recycle ratio of 50 percent is to be employed. Figure 32 shows the three operating states for the minimum, average, and maximum influent flow rate cases described above. In each case the recycle flow rate is greater than required and in no case is the clarifier overloaded or even critically loaded. It is to be noted, furthermore, that the clarifier under flow or recycle line solids concentration remains unchanged regardless of the operational state of the system. This recycle control strategy would provide for stable diurnal operation of an aerator/clarifier system. Nonetheless, the operational costs for this strategy would be slightly higher than for the control strategy described above. Also, a slightly greater degree of turbulence would be imposed on the clarifier.

6. Case of extremely concentrated MLSS and low overflow rates.

a. It was demonstrated above (III.B.3.b.) that a thickening overload in a clarifier can be alleviated by increasing the recycle rate to the extent that the operational state of the clarifier is brought to a critically loaded or underloaded condition. This, however, is not the appropriate remedial measure for the case of extremely concentrated MLSS and low overflow rates; a case which is frequently encountered in industrial situations, particularly in the textile and petrochemical industries.

b. This peculiar case can be illustrated by use of Figure 33. The state point is defined by the coordinate pair (G_0 = 3.47 lbs/ft^2 - day, C_0 = 6400 mg/l). The overflow rate operating line has a slope of 8.67 ft/day (Q_I/A) while the underflow rate operating line has a slope of 87.6 ft/day (u_I). For this operational state it is apparent that the clarifier is overloaded with respect to thickening. In this case, however, the

Influent Flow Case	Qi/A) (gpd/ft^2)	Required Recycle Rate (MGD/pct.)	Flow Proportional Recycle Rate (MGD/pct.)
Minimum (7.72 MGD)	617	2.82/36.5	3.30/42.7
Average (10.29 MGD)	823	4.39/42.7	4.39/42.7
Maximum (12.86 MGD)	1028	6.48/50.4	5.49/42.7

TABLE 5 Recycle Rate Comparison For Three Influent Flow Cases

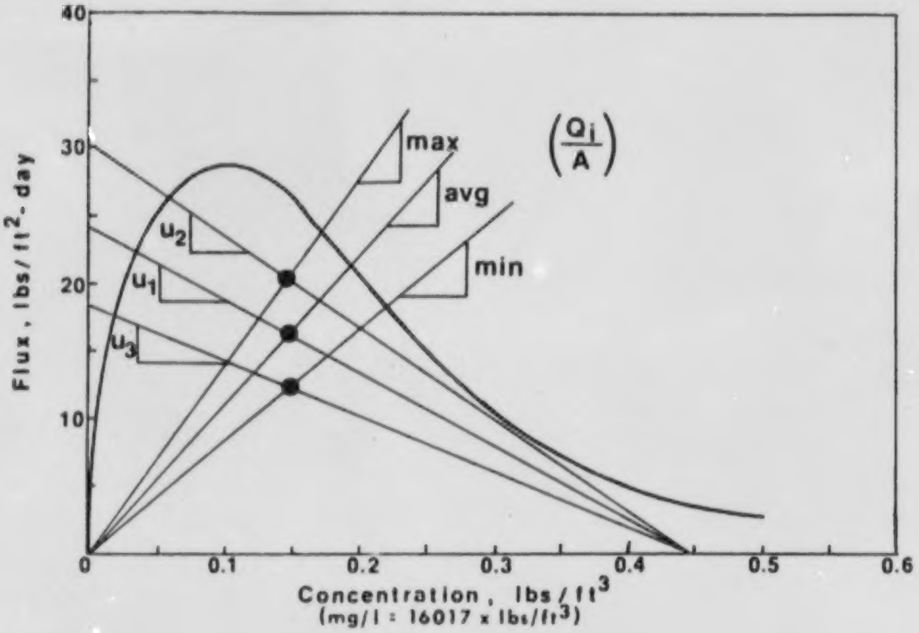

FIGURE 32 Operational States For Flow Proportional Recycle Rate Control

concentration of the limiting layer, C_L is less than C_o, the MLSS concentration. Consequently, the overloaded condition can be resolved only by decreasing the recycle flow rate to 63 ft/day, u_2. This control action serves to poise the operating state of the clarifier at critical loading, a stable operating state.

c. It is important to emphasize, therefore, that thickening overloads are resolved in some circumstances by increasing the recycle flow rate and in others by decreasing the recycle flow rate. Although the former situation is encountered much more commonly, operational strategies cannot be formulated on a priori basis without a

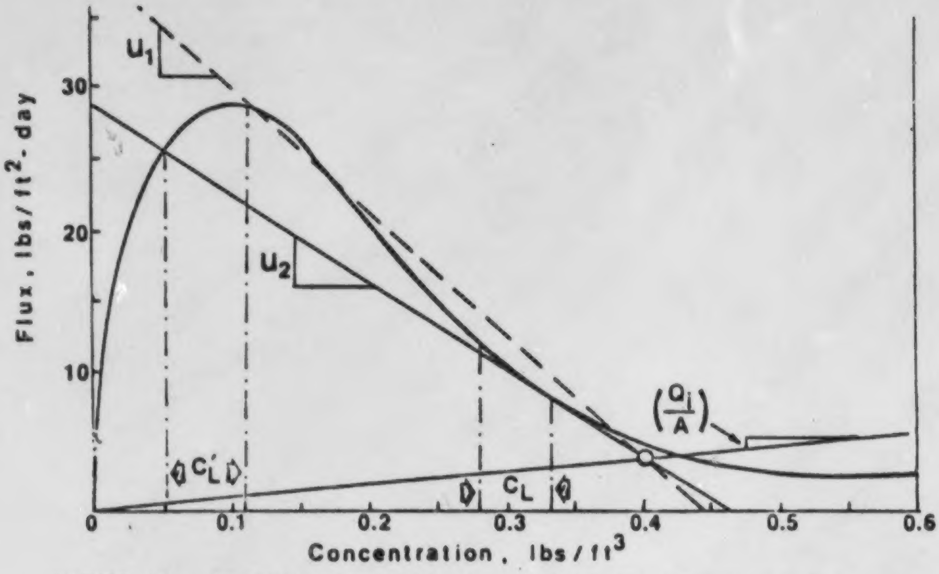

FIGURE 33 Operational State for High MLSS and Low Overflow Rate

knowledge of the operational state of the system.

C. Variable Influent Flow Rate (Clarification Considerations)

1. As for section III.B (Variable Influent Flow Rate - Thickening Considerations), the analysis and control procedure can best be illustrated through example. To better illustrate the cases relating to the clarification aspects of a secondary sedimentation basin, it was necessary to change the design specifications and operation characteristics for the base case. The new parameters are defined as follows:

   *Base Case influent flow rate = 10.29 MGD

   *Mean solids residence time = 5.77 days

   *Volume of aerator = 2.51 MG

   *Clarifier surface area = 26,713 ft^2

   *MLSS (C_0) = 3204 mg/l (0.2 lbs/ft^3)

   *Recycle flow rate (R) = 12.29 MGD (100%)

2. Case of concentrated MLSS with a thickening overload but no clarification overload.

   a. Initially the state point is located as shown in Figure 34 at point (a) and has coordinates of 0.2 lbs/ft^3, 10 lbs/ft^2/day). The recycle rate operating line has a slope equal to 51.5 ft/day (labeled u) while the overflow rate operating line has a slope equal to 385.2 gal/ft^2/day (51.5 ft/day), labeled (Q_I/A).

   b. If the influent flow were then to change stepwise from the base case daily flow, 10.29 MGD, to a flow rate of 22.31 MGD, the state point is seen to shift upward in Figure 34 to point (b). Due to the increased flow the overflow rate operating line has an increased slope, 835 gal/ft^2/day. Since the recycle flow rate was not changed, the new recycle rate operating line (dashed) has simply shifted upward and has the same slope as before the step change was imposed.

   c. Analysis of the new operating state shows that the clarifier is overloaded with respect to its thickening capacity since the recycle rate operating line passes above the settling flux curve. The sedimentation basin, however, is not overloaded with respect to clarification since a dilute blanket concentration (lower limiting concentration, C'_L) that can transmit the entire applied flux exists. This concentration is equal to 0.09 lbs/ft^3 and is labeled C'_{L2} in Figure 34.

   d. If the operator took no control action in response to the imposed hydraulic transient, the system itself would respond, as seen in III.B.3.C, by

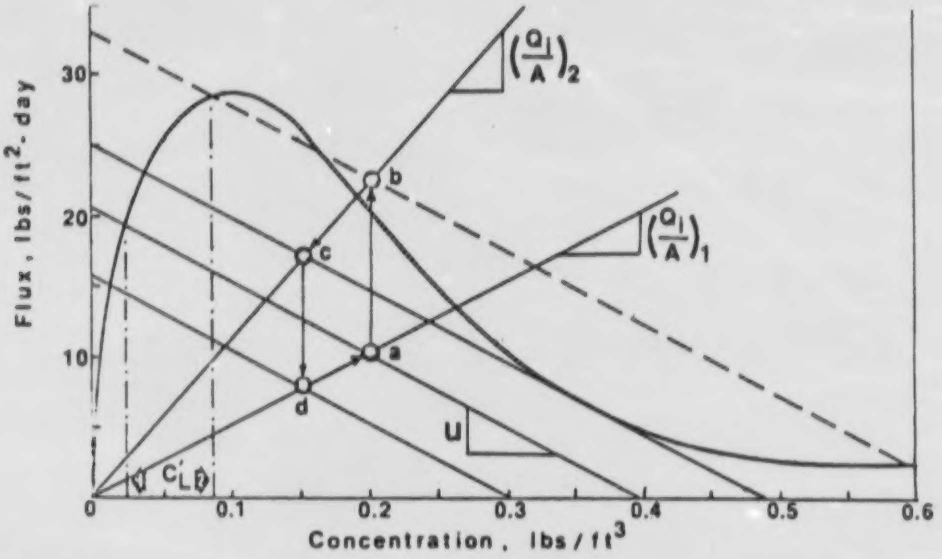

FIGURE 34 Operational States For Increased Influent Hydraulic Flow Rates; Thickening but No Clarification Overload

transferring biological solids from the aerator to the clarifier. This would result in a dilution of the solids in the aerator while a solids blanket (thick) would rise in the clarifier to accomodate the solids that were transferred. The initial and final operating states are described by state points (b) and (c), respectively, in Figure 34. State point (c) is a stable operational state for the aerator/clarifier system.

e. During the transient response, 16,778 lbs. of bio-solids would be transferred from the aerator to the clarifier. These solids would accumulate as a thick blanket in the clarifier at a concentration of 0.36 lbs/ft³ (C_L). The blanket, consequently, would rise approximately 1.74 ft. and then stabilize ad the operating state point approached point (c).

f. If the influent flow rate were subsequently changed stepwise from 22.31 MGD back to the base case value, 10.29 MGD, the operational state would correspondingly shift from point (c) to point (d). As noted above, this operating condition is one in which the clarifier is underloaded with respect to thickening. Solids that are stored in the clarifier in the "blanket" consequently would be transferred from the clarifier back into the aerator. This would be accompanied by a shift in operational states from state point (d) to point (a). At the latter state point the blanket in the clarifier would have been entirely dissipated.

3. Case of Concentrated MLSS with Both Thickening and Clarification Overloads/

a. No Control

(1) This case, illustrated in Figure 36, has initial condition that are identical to the previous case considered, III.C.2. The initial operational state is described by point (a).

(2) If the influent flow were then to change stepwise to a flow rate of 25.58 MGD, the state point is seen to shift upward in Figure 35 to point (b). Due to the increased flow, the overflow rate operating line has an increased slope, 957 gal/ft²/day. As before, since the recycle flow rate was not changed, the new recycle rate operating line (dashed) has simply shifted upward and has the same slope.

(3) Analysis of the new operating state shows that the clarifier is

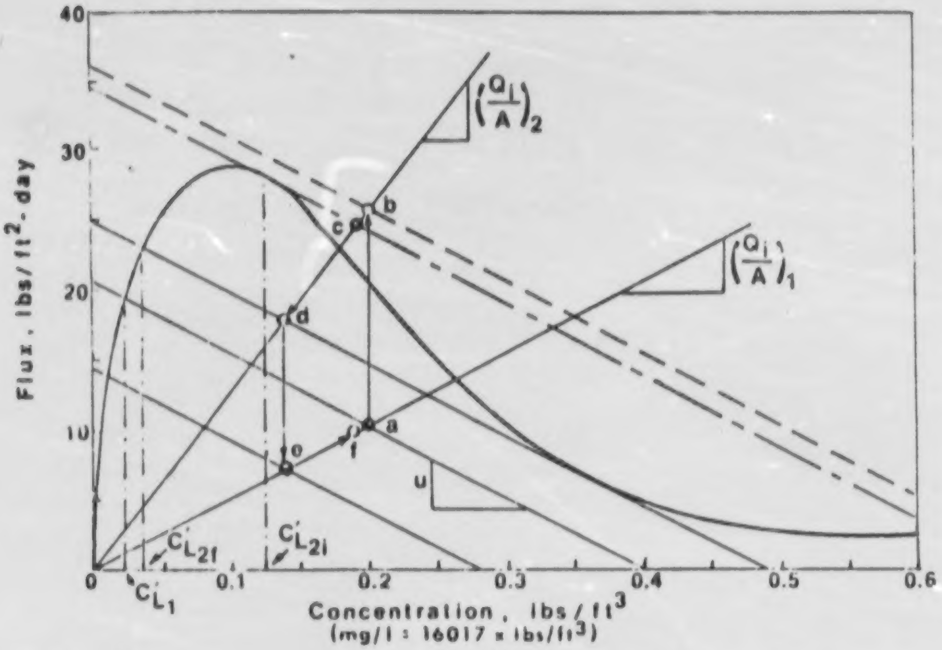

FIGURE 35 Operational States For Increased Influent Hydraulic Flow Rates: Clarification and Thickening Overloads

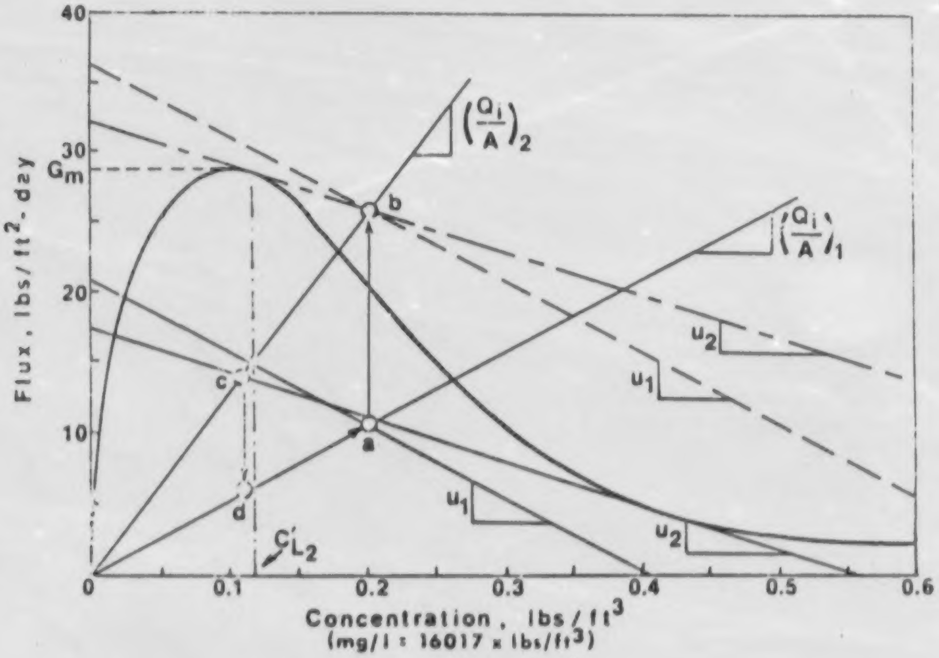

FIGURE 36 Operational States For Increased Influent Hydraulic Flow Rates: Clarification and Thickening Overloads - Control Case 1.

overloaded with respect to both thickening and clarification. It is overloaded with respect to clarification, in this case, because a lower limiting concentration of .125 lb/ft^3 cannot be reached. The maximum flux that can be transmitted by this concentration is 34.5 lbs/ft^2/day. Since a flux of 36.2 lbs/ft^2/day is applied to the clarifier, the clarifier is overloaded by a differential flux of 1.7 lbs/ft^2/day.

(4) After the step change to state point (b), the dilute blanket begins to increase in concentration throughout its entire depth from C'_{L1} to C'_{L2}. This is a gradual change governed by the system's dynamics. Also, because the applied flux is greater than the entire dilute blanket and been scoured into the overflow, then point (f) would describe the final operating state of the system. Of course, if only a portion of the dilute blanket had been scoured into the overflow, then the final operating state point would lie somewhere between (f) and (a).

b. Control Case 1

(1) The initial and forcing conditions for this case, illustrated in Figure 36, are identical to those described under the previous example of no control.

(2) At state point (b) the treatment plant operator has a control option available to him. He can decrease the recycle flow rate to 6.49 MGD (u_2 = 32.5 ft/day). This serves to decrease the applied flux to the extent that the dilute blanket can transmit the total applied flux at a concentration of C'_{L2}. During the transition the dilute blanket should increase in concentation throughout its entire depth from its original value and should approach, but never reach C'_{L2} since state point (b) transiently shifts toward point (c) along the overflow rate operating live.

(3) Because the operator decreased the recycle flow rate, the dilute blanket will not propagate above the feed point since the dilute blanket can transmit all of the solids applied to it.

(4) The control action taken does not serve to eliminate the thickening overloaded condition. all of the applied solids at a concentration of C'_{L2i}, and the dilute blanket will no longer propagate upward above the feed point. As the state point proceeds from (c) to (d), the dilute blanket that has formed above the feed point will feed into the lower regions of the clarifier (thick blanket) and thereby be depleted. When the dilute blanket above the feed point is entirely depleted, the dilute blanket concentration will gradually decrease throughout its entire depth until its concentation attains the level designated by C'_{L2f} and the state point has reached point (d). State point (d) is a stable operating point. The thick blanket would have risen 2.69 ft during the transition.

(7) If the influent flow rate were subsequently changed stepwise from 25.58 MGD back to the average or base case value, 10.29 MDG, the operational state would shift from point (d) to point (e). The clarifier is underloaded with respect to both clarification and thickening for this condition. Solids that are stored in the "blanket" within the clarifier, therefore, would be transferred back to the aerator. This would be accompanied by a shift in operational states from point (e) to state point (f), (a), or somewhere between the two. If no bio-solids were scoured from the dilute blanket (that propagated above the feed point) during the period that it existed, then point (a) would specify the terminal operating state of the aerator/clarifier system. Conversely, if the flux that can be transmitted downward by C'_{L1} and would ultimately approach C'_{L2i}. A total of 2684 lbs. of bio-solids would be transferred from the aerator and stored in the dilute blanket in the clarifier above the feed point. This blanket would propagate upward approximately point is usually located 3 to 4 ft beneath the water surface, this dilute blanket theoretically can

be stored in the clarification zone without resulting in failure. Nonetheless, hydraulic scour from this blanket may lead to clarification failure and loss of some of the biological solids from the system.

(5) As the dilute blanket gradually increases in concentration (From C'_L to C'_{L2}) after the hydraulic transient is imposed, it must pass through the concentration level designated by C'_{L2f}. When the dilute blanket attains this concentration, the clarifier becomes overloaded with respect to thickening also. A thick blanket consequently, forms and propagates upward. The dilute blanket concentration would continue to increase, however, and approach C'_{L2i}.

(6) The fact that (a) solids are accumulating in the dilute blanket below the feed point, (b) solids are accumulating in the dilute blanket above the feed point, and (c) solids are accumulating in the thick blanket, serves to shift the state point from (b) to (d) in Figure 35. When the state point reaches point (c) during the transition, the dilute blanket can transmit Consequently, solids are transferred from the aerator to the clarifier and stored in the thick blanket at a concentration of 0.42 lbs/ft^3 (C_L) as the state point shifts from (b) to (c). A total of 30,872 lbs. of solids would be transferred which would result in the propagation of a 2.75 ft. thick blanket.

(5) It is important to note that this control strategy cannot be implemented if state point (b) has a y-coordinate (G_0) which is greater than the maximum flux attainable by the suspension (G_m). This, of course, is due to the fact that the recycle flow rate has a lower limit of zero.

(6) Moreover, the greater the magnitude of the hydraulic transient that is imposed on the system, the greater is the likelihood that all the solids that are transferred from the aerator to the clarifier cannot be stored or accomodated therein and that some solids therefore, will be scoured into the overflow.

C. Control Case 2

1. The initial and forcing conditions for this case illustrated in Figure 37, are identical to those used for the previous examples.

2. After the hydraulic transient was imposed assume that the operator implemented the control strategy described in the previous example. As described above, the state-point would shift down along the overflow rate operating line from point (b) toward point (c). When the state point reaches point (c), the operator has yet another control action available to him. He can increase the recycle flow rate to 17.05 MGD (u_3 = 85 ft/day). This action serves to bring the clarifier from an overloaded to a critically loaded condition thereby preventing the further transfer of bio-solids from the aerator to the clarifier. State point (c) is a stable operating point.

3. For this control strategy, a total of only 7718 of solids, as compared to 30,872 lbs for Control Case 1, would be transferred to the clarifier. This would result in the propagation of a 1.52 ft thick blanket of concentration 3043 mg/l (0.19 lbs/ft^3). For this control case the solids in the aerator would dilute out to approximately 2850 mg/l as compared to 1760 mg/l for Control Case 1. It is apparent, therefore, that this control strategy serves to minimize the mass of solids transferred from the aerator to the clarifier.

4. Case of Dilute MLSS

   a. The initial operational state for this case, illustrated in Figure 38, is described by point (a) which has a coordinate pair of (0.05 lbs/ft^3, 8.5 lbs/ft^2/day). The overflow rate operating line has a slope of 160 ft/day (1200 gal/ft^2/day) while the underflow rate operating line has a slope of 51 ft/day. It is to be noted that this illustrative example is not referenced to either of the system designs specified under section III.B or III.C. Rather, this case will be described from a generalized viewpoint.

   b. If the influent flow were then to change stepwise such that the state point shifted to point (b), the overflow rate operating line has an increased slope, 45 ft/day (4084 gal/ft^2/day). Since the recycle flow rate was not changed, the new recycle rate operating line (dashed) has a simply shifted upward and has the same slope.

   c. For this case, the lower limiting concentration (C'_l) is equal to the

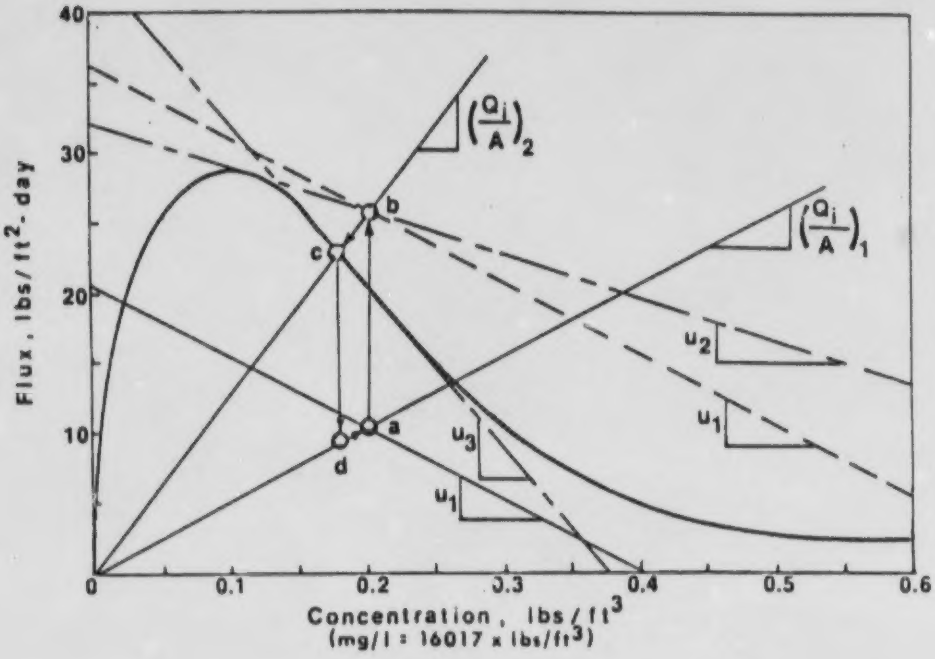

FIGURE 37 Operational States For Increased Influent Hydraulic Flow Rates: Clarification and Thickening Overloads - Control Case 2

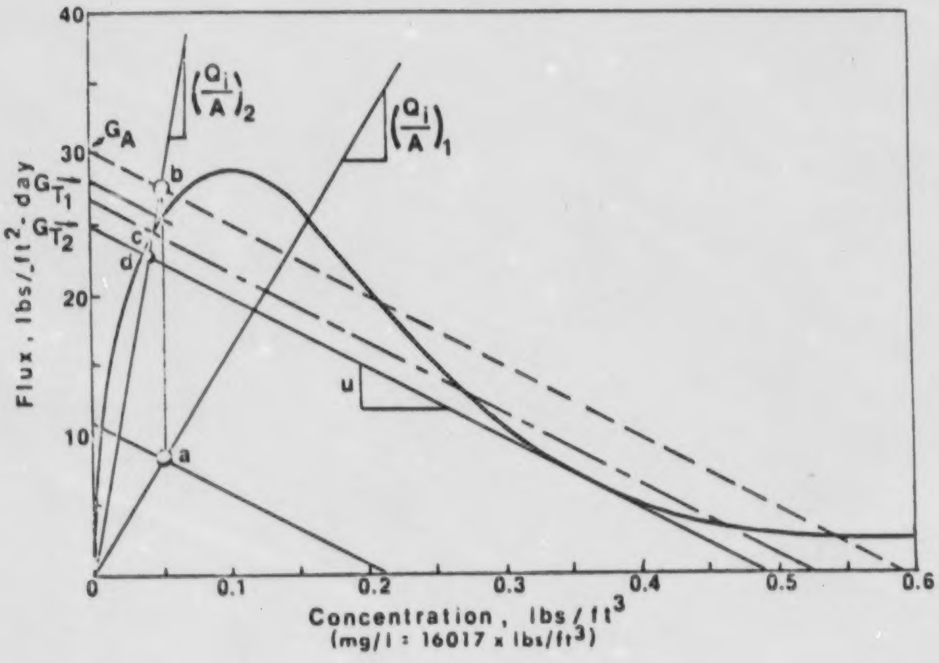

FIGURE 38 Operational States For Increased Influent Hydraulic Flow Rates Case of Dilute MLSS.

MLSS Concentration (C_0) since there is no more dilute concentration that is stable. For this condition a flux of 28.2 lbs/ft^2/day (G_{T1}) can be transmitted to the bottom of the clarifier by the dilute blanket. Since a flux of 30 lbs/ft^2/day is being applied (G_A), a net flux of 1.8 lbs/ft^2/day would accumulate as a blanket of concentration C_0 which would form at point. This blanket, of course would propagate upward to accomodate the imbalance in flux between that which is applied (G_A) and that which transmitted (G_{T1}).

d. For this condition it is apparent also that the thickening function of the clarifier is overloaded. The thick blanket can transmit a flux of 25 lbs/ft^2/day (G_{T2}).

Since a flux of 28.2 lbs/ft^2/day is applied to the thickener portion of the clarifier via the dilute blanket, a differential flux of 3.2 lbs/ft^2/day would accumulate in the bottom at a concentration of C_L.

e. Because the clarifier is over-loaded with respect to both clarification (G = 1.8 lbs/ft^2/day) and thickening (G = 3.2 lbs/ft^2/day, bio-solids will be transferred from the aerator to the clarifier. As noted above, these solids will accumulate both as a thick blanket near the bottom and as a dilute blanket above the feed point. As this occurs the solids in the aeration basin become more dilute and the state point shifts from point (b) down along the overflow rate operating line.

f. When the state point reaches point (c), the dilute blanket is able to transmit all of the applied solids into the thickening zone. At this point the applied flux is equal to 27.2 lb/ft^2/day. Because this exceeds G_{T2} (25 lbs/ft/day, solids continue to accumulate in the thickening zone until the state point reaches point (d)--a stable operating state point. During the transition from point (c) to (d) the dilute blanket that had formed at the feed point and propagated upward would feed into the thickening zone via the dilute blanket and would thereby be dissipated.

g. An operator has no control options available to him for this case.

5. Special Case of High Recycle Rate

a. Case of MLSS = 2403 mg/l

(1) The initial operation state for this case, illustrated in Figure 39, is described by point (a) which has a coordinate pair of (0.15 lbs/ft^3, 16 lbs/ft^2/day and the underflow rate operating line has a slope of 160 ft/day. Again, this illustrative example is not referenced to either of the system designs specified under Sections III.B or III.C.

(2) It is apparent in Figure 39 that the slope of the recycle rate operating line is greater than the slope of the descending limb of the settling flux curve. For this condition, therefore, the clarifier can never be overloaded with respect to its thickening function since no stable thick blanket concentration, C_L, exists. Simply, all the solids introduced into the clarifier would be transmitted to the bottom at a concentration of C'_L.

b. Case of MLSS = 4004 mg/l

(1) The initial operational state for this case is described by state point (b) in Figure 39. Because the state point lies outside the envelope described by the settling flux curve and the slope of the recycle rate is greater than the falling limb of the settling flux curve, the lower limiting concentration C_L) is equal to the MLSS concentration (C_0) since there is no more dilute concentration that is stable. Moreover, the clarifier is overloaded with respect to clarification but not with respect to thickening.

(2) Since the clarifier is overloaded with respect to clarification (the flux described by b' can be transmitted at the bottom), bio-solids will be transferred from the aeration basin to the clarifier. These would accumulate as a blanket of concentration C_0 which would form at the feed point and propagate upward to accomodate the imbalance in flux (Δ). During the transition the state point would move down along the overflow rate operating line toward point (a). The state point would stabilize at the intersection of the overflow rate operating line and the settling flux curve. The dilute blanket (C_0) would then also stabilize above the feed point.

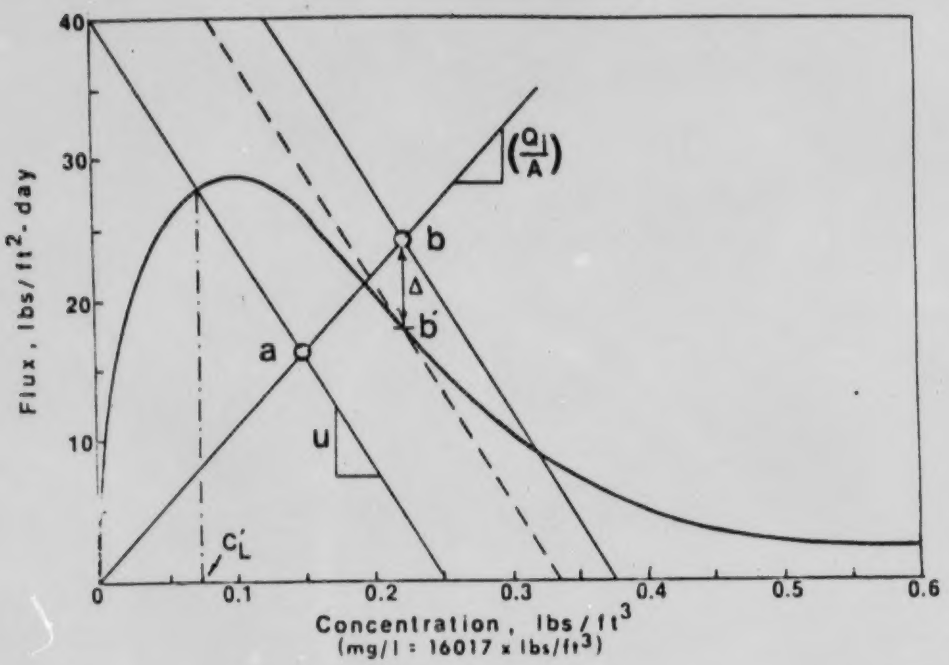

FIGURE 39 Operational States For High Recycle Rates

D. Changes in Sludge Settling Characteristics

1. In the preceeding analysis it was assumed that the settling characteristics of the sludge did not change in the time-scale considered. It must be recognized, nevertheless, that sludge settling characteristics do change seasonally and often in much shorter time domains (e.g. monthly, weekly, and daily). Such changes can usually be attributed to changes in either solids residence time, temperature or biomass population distributions.

2. Two settling flux curves are shown in Figures 40; one for the base case and the other for a degraded settling sludge. If one assumed that the activated sludge system were operated for the base case as described in Section III.b and by the state point having coordinates of (0.15 lbs/ft^3/day, and the two operating lines of slopes (Q_i/A) avg/ and u_l, and that the settling characteristcs subsequently deteriorated, then it is apparent that the clarifier would be overloaded. To prevent the transfer of bio-solids from the aerator to the clarifier, the operator could simply increase the recycle flow rate from 4.30 to 5.98 MGD (58.1 percent of the influent flow) which corresponds to a u_2 of 64 ft/day and the condition of critical loading.

3. It is again important to underscore the statement that settling flux curves must be updated with sufficient frequency to provide an accurate description of the current sludge settling characteristics. The required frequency for such updating measurements depends on the sludge itelf as well as the physical, chemical, and biological characteristics of the wastewater and the operational state of the activated sludge system. Only with truly current settling flux curves can the utility of the operational state analysis and control approach established herein be realized.

E. Changes in Solids Residence Times

1. It is occasionally desirable to change the operational set-point of solids residence time for an activated sludge system. This is easily accomplished by changing the solids wasting program. Such changes in operational state can be illustrated using the batch settling flux operations analysis approch. To do so it has been assumed, for example, that θ_c is to be changed from 5.8 days (base case defined in Section III.b) to 7.1 days. This, of course, is accomplished by decreasing the rate at which bio-solids are wasted from the system which results in an increase in the concentration of mixed liquor suspended solids.

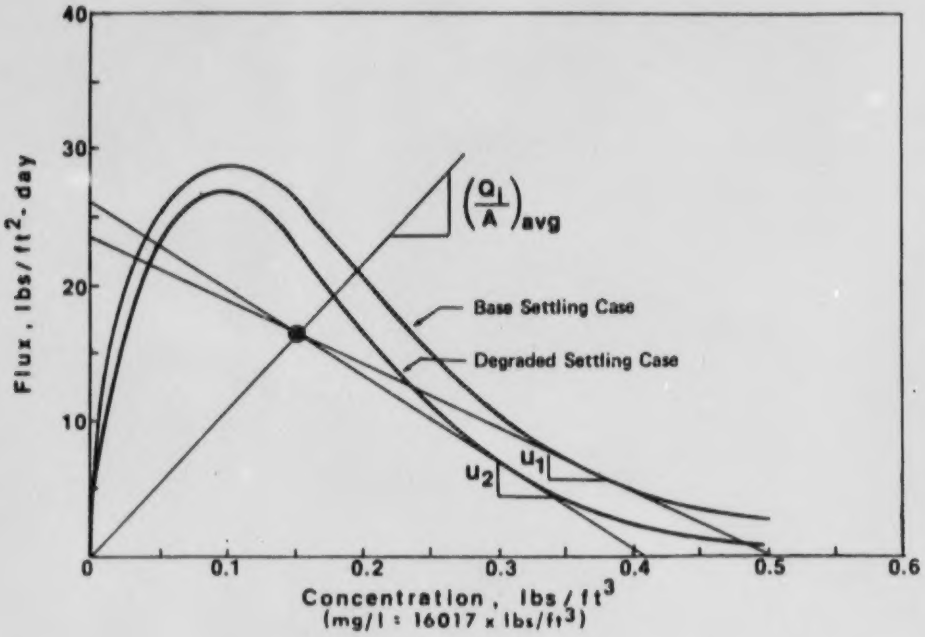

FIGURE 40 Operational States For Changed Settling Characteristics

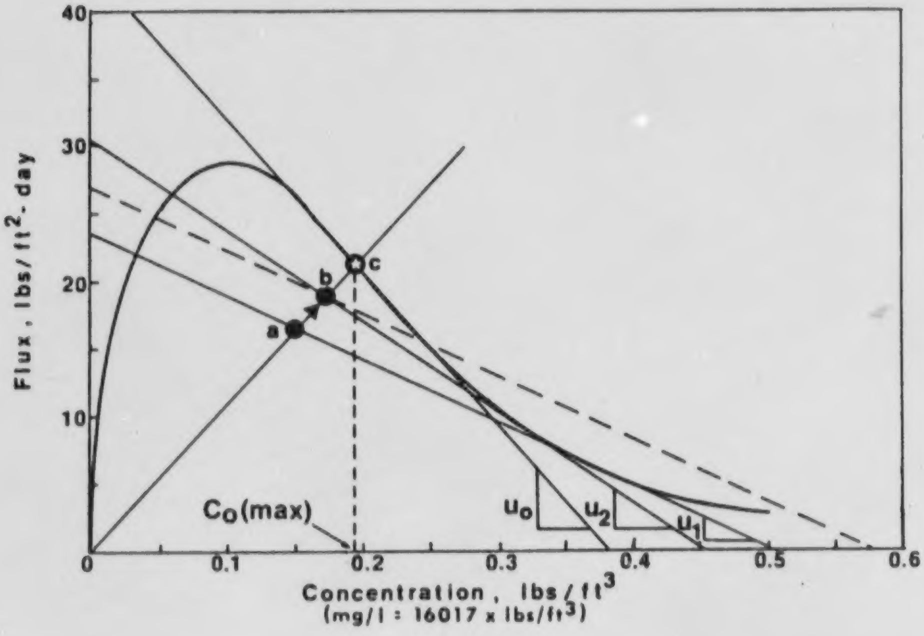

FIGURE 41 Operational States For Increased Solids Residence Times

Figure 41 illustrates the transition; i.e. the operating point shifts along the overflow rate operating line from state point (a) to point (b).

2. If the plant operator did not change the recycle flow rate during the transition, (dashed line) it is apparent that the clarifier would be overloaded at state point (b) and that the net increase in the mass of bio-solids would be transmitted to the clarifier and stored there. To retain those solids in the aerator the operator would have to increase the recycle flow rate to 62.8 per cent of the average influent flow ($U_2 = 68$ ft/day). This corresponds to a stable operational state. The salient required operating conditions have been tabulated in Table 6.

3. Conversely, if the operator wanted to decrease the solids residence time set-point from 5.8 to 3.8 days, he would simply increase the solids wasting program. This would result in a net loss of bio-solids and, therefore, a lower concentration of mixed liquor suspended solids. This transition is illustrated in Figure 42 by a shift of the state point along the overflow rate operating line from state point (a) (base case) to point (d). It is apparent that the recycle flow rate at state point (d) is higher than required (dashed line). To minimize recycle pumping operating costs and the degree of turbulence imposed on the clarifier, the recycle flow rate could be decreased to 23.6 percent of the 10.29 MGD average influent flow rate ($u_3 = 26$ ft/day).

TABLE 6 Recycle Rate Comparison For Three SRT Values

Case	SRT (θ_c) (days)	MLSS (C_o) (mg/l)	Required Recycle Rate (R) (percent)
Ave.	5.8	2403	42.7
High	7.1	2803	61.8
Low	3.8	1762	23.6
Max.	8.2	3076	104

4. Another consideration that must be established related to the state point, shown in Figure 41, that lies at the intersection of the settling flux curve and the overflow rate operating line, state point (c). State point (c) establishes the maximum θ_c and the corresponding C_o at which the biological system could be operated in a stable condition. For the current example θ_c is

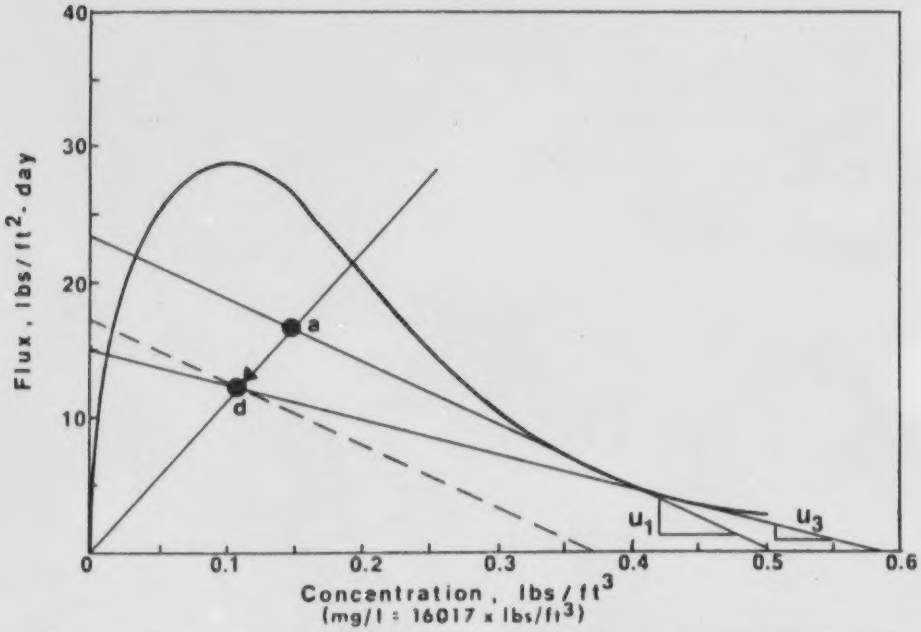

FIGURE 42 Operational States For Decreased Solids Residence Times

limited to a maximum if 8.2 days. This corresponds to a C_0 of 3076 mg/l at the average hydraulic flow rate.

5. It is to be noted, however, that a sludge's settling characteristics usually change when θ_c is changed. One would have to consider such changes when conducting an operational state analysis with respect to changes in the solids residence time.

F. On-Line, Real-Time Determination of Settling Flux Curves

1. Two methods for determining settling flux curves were described under section I.F.4. Both methods require that a sample of the slurry be obtained from an operating activated sludge system and transported to the location of the test apparatus. During the process of collecting and transporting the slurry a high probability exists that the settling characteristics of the slurry will be altered. The test interface settling velocity apparatus and the operating clarifier are markedly different geometrically. It is probable then, that settling velocities measured in a small diameter cylinder (6-8 inches) are not truly indicative of the settling characteristics that are observed in the operating clarifier. A procedure using an operating clarifier for determining the settling flux curve is not subject to these two limitations, and should be used when possible.

2. The procedure for developing settling flux curves using an operating clarifier is:

   a. Clarifier originally is in an underloaded state;

   b. Operator decreases recycle flow rate to overload the clarifier;

   c. Operator ensure that clarifier is overloaded by observing a rising thick sludge blanket;

   d. Operator measures suspended solids concentration in the recycle line, (C_u);

   e. Operator calculates bulk transport velocity component ($U = R/A$);

   f. Operator plots recycle operating line with X-intercept (C_u) and slope U (Figure 43);

   g. Operator repeats procedures (a) through (f) for several different flow rates to plant (Q_i);

   h. Operator establishes settling flux curve (thickening segment) from envelope

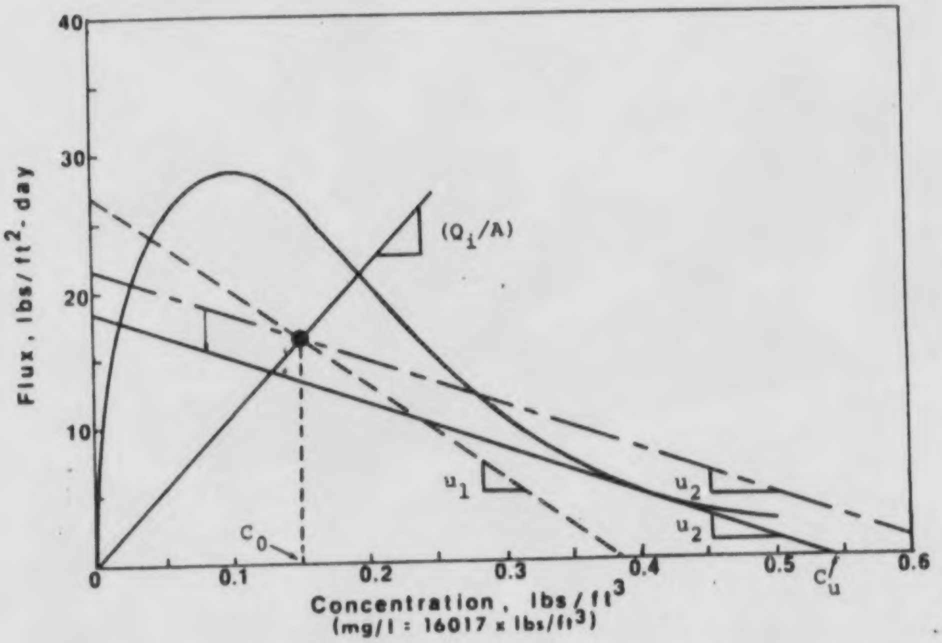

FIGURE 43 On-Line, Real-Time Determination of Settling Flux Curves - Dynamic Forcing

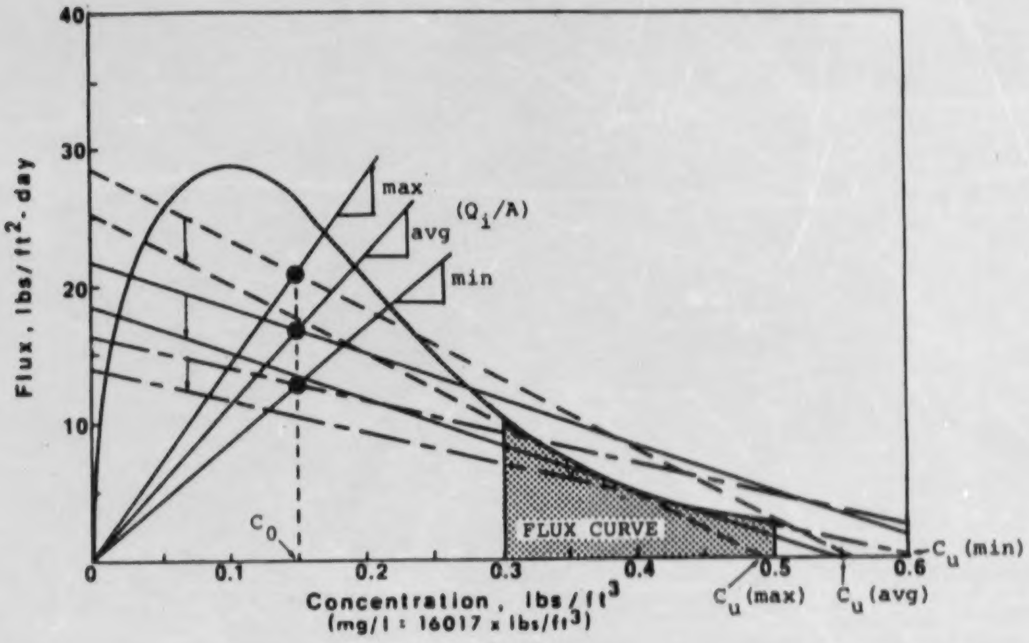

FIGURE 44 On-Line, Real-Time Determination of Settling Flux Curves Thickening Limitation Envelope

described by recycle rate operating lines (Figure 44).

3. It is to be noted that this procedure provides settling flux data only for that region of the settling flux curve that limits the thickening function of a clarifier. Although a similar procedure can be specified for defining the clarification portion of the curve, it is not recommended because the clarifier would have to be forced to the point of incipient failure. The clarification portion should be defined, consequently, using the test procedures defined in section I.F.4.

NOTATION

A = surface area of secondary clarifier, L^2

C_0 = concentration of bio-solids in aeration basin, ML^{-3}

C_e = effluent suspended solids in clarifier overflow ML^{-3}

C_L = solids concentration in thick blanket, ML^{-3}

C'_L = solids concentration in dilute blanket, ML^{-3}

C_u = solids concentration in underflow, ML^{-3}

G = total flux, $ML^{-2}T^{-1}$

G_0 = solids flux due to infulent flow, $ML^{-2}T^{-1}$

G_b = bulk flux, $ML^{-2}T^{-1}$

G_s = settling flux, $ML^{-2}T^{-1}$

k_d = decay rate of bio-solids, T^{-1}

Q_i = flow rate to plant, L^3T^{-1}

R = recycle flow rate, L^3T^{-1}

S = concentration of soluble substrate in effluent, ML^{-3}

S_0 = concentration of substrate in influent ML^{-3}

u = underflow withdrawal velocity, LT^{-1}

v = gravitational sedimentation velocity, LT^{-1}

V = volume of aeration chamber, L^3

w = waste flow rate, L^3T^{-1}

y = true yield coefficient, MM^{-1}

θ = hydraulic residence time, T

θ_c = solids residence time, T

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This report was prepared by Dr. Thomas M. Keinath, Professor, & Head of Environmental Systems Engineering, Clemson University, Clemson, South Carolina, 29631.

UNIT PROCESS DESIGN - DISINFECTION

UNIT 10

UNIT 10 - UNIT PROCESS DESIGN - DISINFECTION

OBJECTIVES

At the conclusion of this presentation, the attendee should be able to:

- Identify the reasons for the use of disinfection techniques.
- List four ways in which disinfection techniques are thought to kill microorganisms.
- Utilize the formula for disinfectant kill including varying concentrations.
- Identify three disinfectants in use in the United States.
- List at least six absolute design considerations relative to disinfectants.
- Describe acceptable chlorine tank monitoring methods.
- Design safe, efficient, effective chlorine enclosures.
- Discuss methods to insure that fuel control systems are designed for operability.
- Discuss design methods to enhance safe movement of disinfectants in the facility.
- Define purpose of injectors and give one "design hint".
- Discuss the mixture of gases and wastewater.
- State the reason for residual control.
- Discuss the importance of adequate detention time and identify at least three means of providing good contact.
- Identify an acceptable drainage plan for disinfection facilities.

UNIT 10 - UNIT PROCESS DESIGN - DISINFECTION

Primary and secondary treatment are designed to reduce organic and suspended solids concentration in the wastewater stream. As such, removal or destruction of pathogenic organisms is not a major consideration in these two treatment processes. The major mechanism by which microbes are removed during primary and secondary treatment is by settling of organisms associated with solids. Pathogenic microorganisms not associated with sewage solids or incorporated into secondary sludge flows are discharged in the final effluent. Thus, disinfection, as a final step in the treatment train, is required to produce an effluent that is low in the concentration of microorganisms that may cause disease.

A. Effects of Disinfectants

There have been four mechanisms proposed to explain the action of disinfectants. Damage to the cell wall may cause cell lysis and death. The disinfecting agent may alter cell membrane permeability and allow nutrients to escape. If the colloidal nature of the cell contents is changed (e.g., protein denaturation), death will result. Finally, disinfectants may inhibit enzyme activity and thereby prevent synthesis of vital products and alter cellular activity.

B. Dosage Considerations

It has been found that, for a given concentration of disinfectant, the longer the contact time, the greater the kill. This observation was first formalized by Chick in 1908:

$$N = N_0 e^{-Kt}$$

Where:

K = First order rate constant
t = Time
N_0 = Number of organisms at time = 0
N = Number of organisms at time = t

The kinetic expressions apply for only a single disinfectant dosage. Varying disinfectant concentrations can be taken into account by using the following empirical expression.

$$C^n t = \text{Constant}$$

Where:

C = Concentration of disinfectant
t = Time required for a specified % reduction
n = A constant, which is based on characteristics of the disinfectant used

From these equations, it can be seen that there are several factors which influence the rate of disinfection. Among these are the number of organisms present in the wastewater, the type and concentration of disinfectant, and the contact time provided between the organisms and the disinfecting agent. Additionally, other parameters have been shown to affect the rate of kill. Increasing temperature results in a more rapid kill. The effectiveness of a disinfectant can depend on the nature and condition of the target species. For example, growing cells are more subject to attack than spores and E. coli is more resistant to disinfectants than certain Salmonella species. The nature of the suspending medium influences the effectiveness of disinfection (e.g., turbidity can absorb a disinfecting agent and can protect microorganisms by entrapping them).

C. Types of Disinfectants

Of all the disinfectants available, chlorine is the most widely used. This chemical is efficient, fairly non-toxic to higher organisms in the concentrations used and relatively inexpensive. Other halogens, such as iodine, are more efficient disinfectants than chlorine but are much more expensive. Ozone is the only other alternative that is used in any quantity in the United States. However, currently its application as a disinfectant is primarily with tertiary effluents. It has been used with secondary effluents, but chlorination backup has been provided. Since the production of ozone is energy intensive, its future as a disinfectant depends upon the future costs of energy (see Table 10.1).

D. Absolute Design Considerations

There are several factors that must be examined when designing a disinfection facility. In selecting a disinfectant, the designer should consider the effectiveness, availability, required dose range and safety aspects of the alternatives. The need for dechlorination in some applications should be considered. The method of addition and mixing are important because they insure that the organisms and disinfectant are property contacted. Accurate metering of the disinfectant is essential to guarantee that the desired dosage is being applied. The contact tank should be designed to preclude short-circuiting, which would greatly reduce the effectiveness of disinfection.

E. Storage

Chemical facilities should be designed with ease of storing and handling in mind. If chemicals are to be delivered in bulk, then ample space must be alloted for storage near the chlorination building with provisions for truck access and efficient transfer of chemicals. Sodium hydroxide safety

TABLE 10.1

RANKING OF ALTERNATIVE DISINFECTANTS FOR WET WEATHER OVERFLOWS

Characteristic	Chlorine Gaseous	Chlorine Sodium hypochlorite	Chlorine dioxide	Ozone
1. Stability of stored chemicals	Excellent	Good	Excellent	N/A
2. Safety of stored chemicals	May be hazardous	Safe	May be hazardous	N/A
3. Produces residual for feed-back dosage control	Yes	Yes	No	No
4. Ability of equipment to accurately dose widely varying flows	Excellent	Excellent	Excellent	Poor
5. Installation cost	Low	Low	Moderate	High
6. Operation and maintenance cost	Low	Low	Moderate	High
7. Requirement for operator attention for equipment start up	Probably required	Desirable	Required	Required
8. Number of full-scale applications in storm-water disinfection	Many	Many	Few	None
9. Relative complexity of equipment required	Moderate	Low	High	High

equipment should be supplied when ton cylinders of chlorine are being handled (see Figure 10.1).

F. Chlorine Tank Monitoring

When chlorine cylinders are being used, two scales of the indicating and recording type are recommended for weighing cylinders in use. These should be used to weigh on-line cylinders continuously so that operating continuity is assured. Each scale should be sized to accommodate the maximun number of cylinders required to deliver chlorine at the maximum feed rate. Adequate means for supporting cylinders on the scales should be provided and the scales should be constructed of corrosion resistant material. Separate manifolds should be provided for the bank of cylinders on each scale and be valved so that one bank of cylinders may be replaced while chlorine is being withdrawn from the other

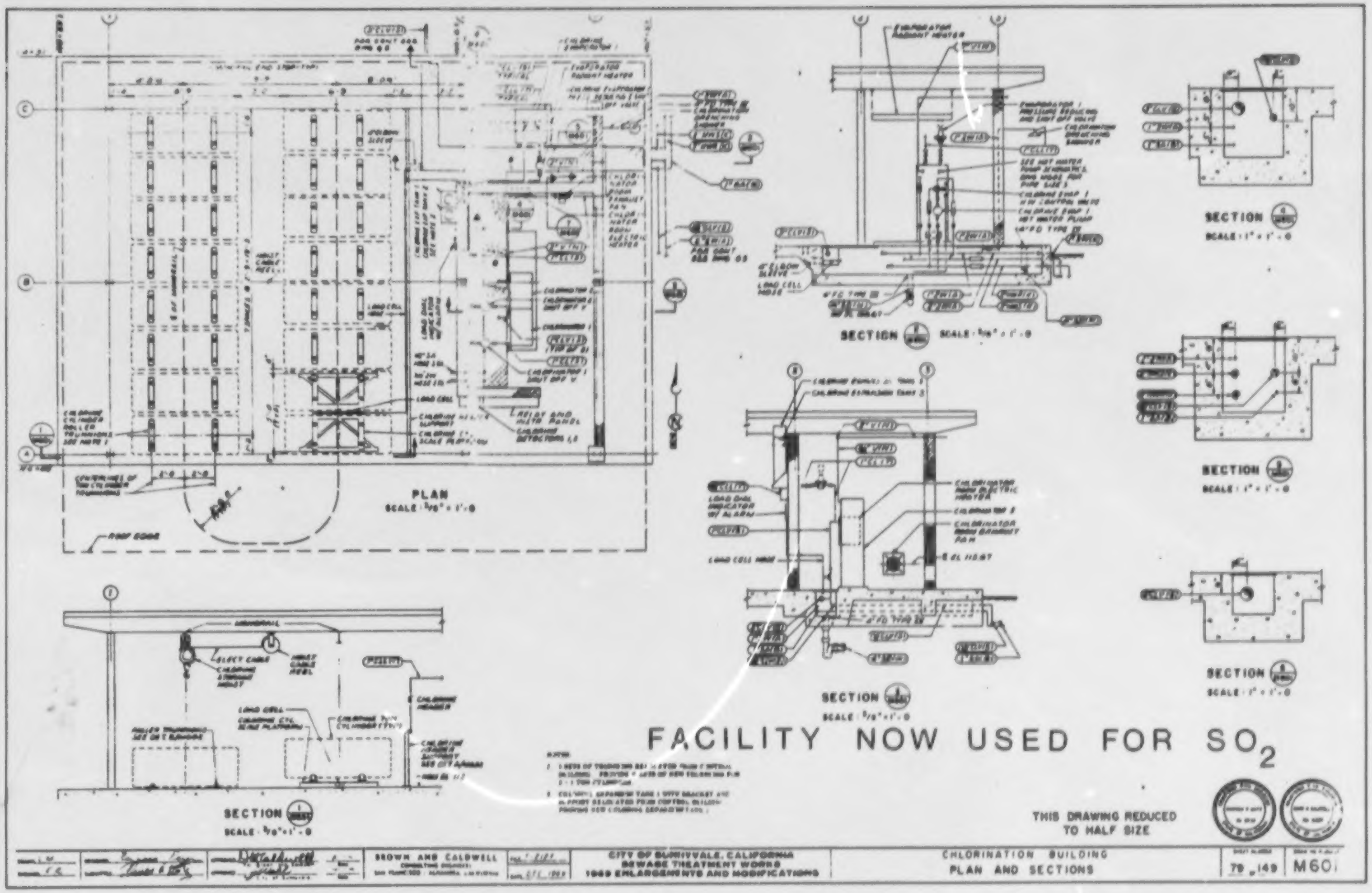
PLAN
SCALE: 3/16" = 1'-0
SECTION
SCALE: 1" = 1'-0
FACILITY NOW USED FOR SO2
THIS DRAWING REDUCED TO HALF SIZE
BROWN AND CALDWELL
CITY OF SUNNYVALE, CALIFORNIA
SEWAGE TREATMENT WORKS
1969 ENLARGEMENTS AND MODIFICATIONS
CHLORINATION BUILDING
PLAN AND SECTIONS
79 - 149
M601

FIGURE 10.1 SODIUM HYDROXIDE SAFETY SYSTEM

bank. Change of withdrawal from one bank to the other should be automatic when the one being used becomes empty. In smaller plants, a small cylinder of chlorine may serve as back-up while the large cylinders are being changed out.

G. Design and Enclosures

Although all equipment should be protected from the elements, minimum enclosure should be provided if weather conditions permit. Gaseous chlorine and chlorination equipment rooms should be isolated from other sections of the chlorine building by gas tight connections. All doors and rooms containing gas chlorination equipment and rooms used for chlorine gas storage should open only to the outside of the building. Multiple exits should be provided for each room where chlorine gas is used or stored. Floor drains from chlorine rooms should not be connected to floor drains from other rooms. Chlorination storage containers and equipment should never be allowed to get below 60 degrees F. Radiant heat is recommended for open enclosures.

All enclosures that involve chlorine handling should have floor level, high capacity, powered exhaust and gravity supply ventilation. Forced mechanical ventilation should cause one complete air change per minute (60/hr) when the room is occupied and one change each three minutes (20/hr) when the room is unoccupied. Air exhaust from chlorine rooms should be near the floor and the point of discharge should be located where it will not contaminate the air inlet to other buildings or inhabited areas.

H. Feed Control Systems

There are several different chlorine feed control systems available. More refined controllers are capital and maintenance intensive but provide a finer degree of feed regulation than less expensive models. The types of controllers available re discussed briefly below in increasing order of feed regulation capability. The simplest types of control systems are either a manual controller which sets feed rate by hand or a timer in which chlorine injection rate is varied according to time of day. Also, the injection rate can be varied according to flow in the wastewater stream. This mechanism requires an effluent flow meter. A residual controller bases disinfectant feed rate on the chlorine residual downstream from the point of injection. This system is fairly complex but wastes little chlorine in the feed. The most complicated system and, from a chemical use standpoint, the most economical, bases chlorine feed rate on a combination of wastewater flow and chlorine residual (see Figure 10.2).

I. Movement of Disinfectant Within a Facility

The mode of transportation of disinfectant to the point of injection depends upon the quantity of disinfectant being moved and the distance over which it must travel. Pressure is generally used to move small quantities of chlorine gas from cylinders to chemical feed equipment in which case heavy black iron pipe is required. If the gas moves too slowly, local freezing of piping may result. The gas should always be clean and dry when using this mode of transportation. Safety considerations restrict the distance over which the gas can be moved. Chlorine gas under vacuum is coming into wider use because of the inherent safety of transport and rapid control response over long distances. This means of transportation has been used successfully for distances of over 10,000 feet. Fiberglass or PVC piping

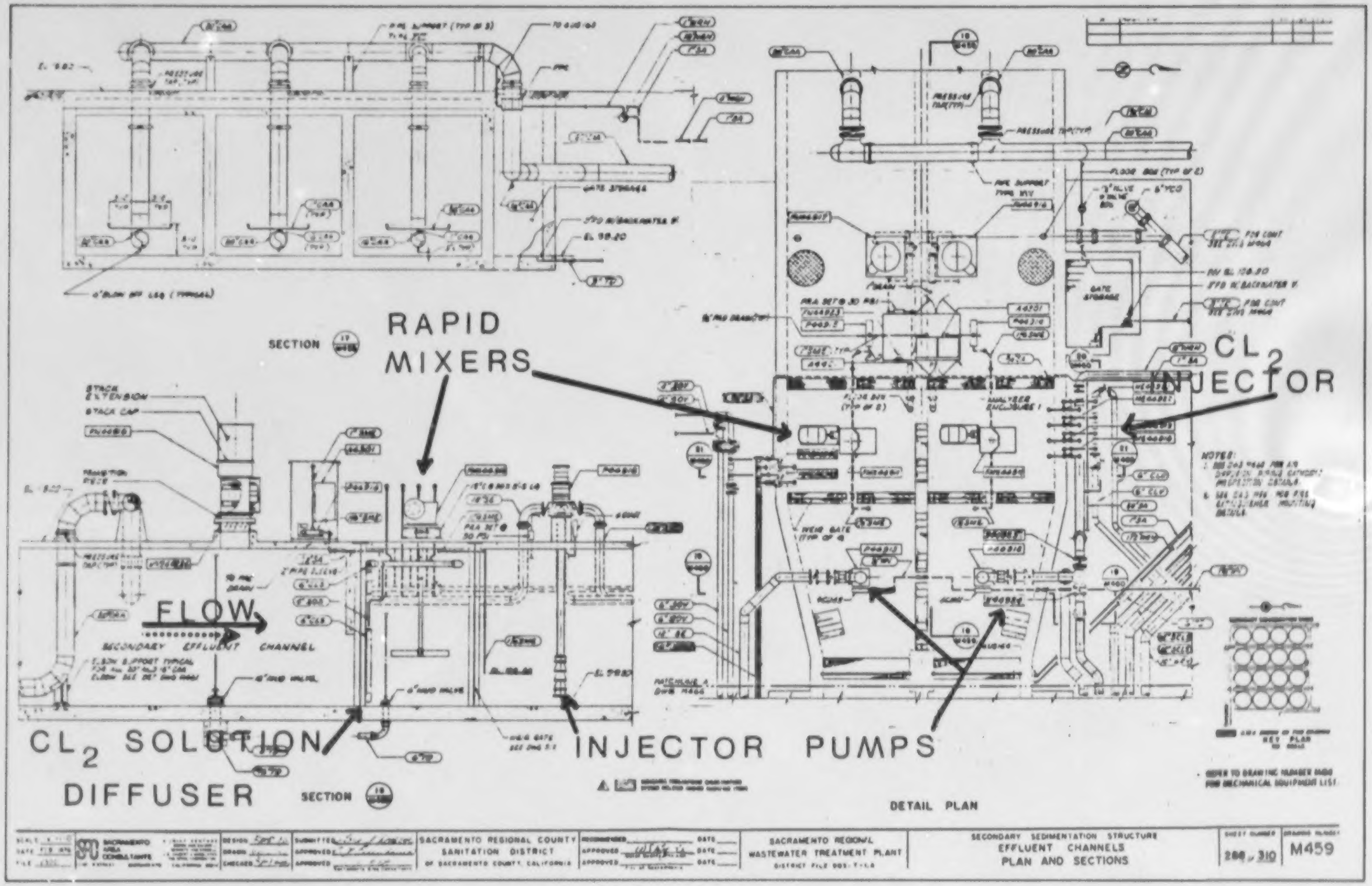
RAPID
MIXERS
CL2
INJECTOR
FLOW
SECONDARY EFFLUENT CHANNEL
CL2 SOLUTION
DIFFUSER
INJECTOR PUMPS
SECTION
SECTION
DETAIL PLAN
NOTES:
KEY PLAN
SACRAMENTO AREA CONSULTANTS
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT
OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
SECONDARY SEDIMENTATION STRUCTURE
EFFLUENT CHANNELS
PLAN AND SECTIONS
288 310
M459

FIGURE 10.2 FEEDBACK CONTROL SYSTEM FOR CHLORINE INJECTION

is required as conduit. Water solution is the most common method of transport over relatively short distances. Rubber or saran-lined pipe is generally used, although PVC is also acceptable. High friction losses in piping and delayed response times make transport over long distances impractical.

J. Injectors

Injectors are generally used to get the disinfectant into the wastewater stream. If chlorine injectors are operated using water pressure, they should be separated from the remainder of the plant water system. If not, the injectors may not function properly when high pressure water is being used for other purposes (e.g., cleaning sedimentation tanks).

K. Mixing

It is important that there be rapid thorough mixing of chlorine into the wastewater. The reaction must be completed quickly if disinfection is to be as efficient as possible. Mechanical mixing can be provided by pumps, propeller or turbine type mixers. These should operate under confined conditions to assure complete mixing. Often head losses at the downstream control gates on secondary effluent channels can provide sufficient energy for mixing of disinfectant and wastewater. Flow should pass through the critical depth to achieve maximum agitation (see Figure 10.3).

If residual control is used for the chlorine feed rate, the effluent sample is taken downstream from the point of mixing. This sample can be used as a final check on the quality of the secondary effluent. This can be done by installing an automated recording turbidimeter in the same line that is used for checking chlorine residual (see Figure 10.4).

A sufficient detention time of chlorinated wastewater is required to assure maximum destruction of pathogenic organisms (see Figure 10.5). Chlorine contact chambers have been designed to serve this function. Dual chambers should be constructed to provide reliability of operation when one chamber needs to be removed from service for maintenance or cleaning. The ideal contact chamber is a pipeline. However, dechlorination becomes difficult using piping. Therefore, an open channel chamber with baffles to prevent short circuiting is used in many plants (see Figure 10.6).

L. Solids Removal and Drainage

Solids deposition in contact chambers can be prevented by using air to provide continuous agitation of the effluent. Vacuum removal of solids similar to that used in swimming pools can be used. This has an advantage over air agitation in that a chamber does not have to be taken out of service. However, vacuum removal is more labor intensive than agitation.

Drains should be included in contact chambers. These should be capable of emptying the chambers completely and rapidly. The drain should discharge into the influent sewer to the plant.

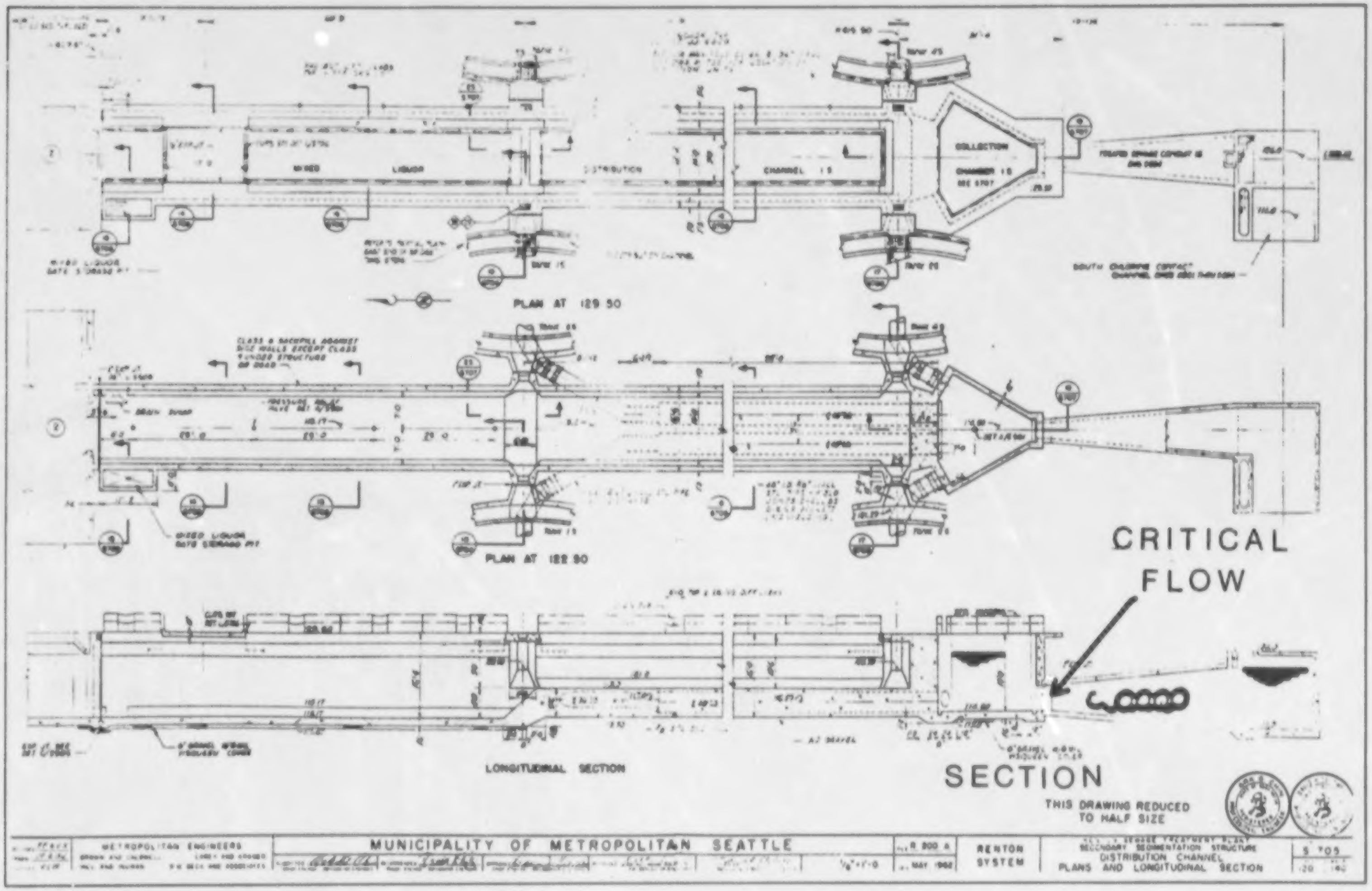
COLLECTION CHAMBER
MIXED LIQUOR DISTRIBUTION CHANNEL
PLAN AT 129.50
PLAN AT 122.90
LONGITUDINAL SECTION
CRITICAL FLOW
SECTION
THIS DRAWING REDUCED TO HALF SIZE
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
RENTON SYSTEM
SECONDARY SEDIMENTATION STRUCTURE
DISTRIBUTION CHANNEL
PLANS AND LONGITUDINAL SECTION

FIGURE 10.3 CHLORINE CONTACT CHAMBER WITH CRITICAL DEPTH

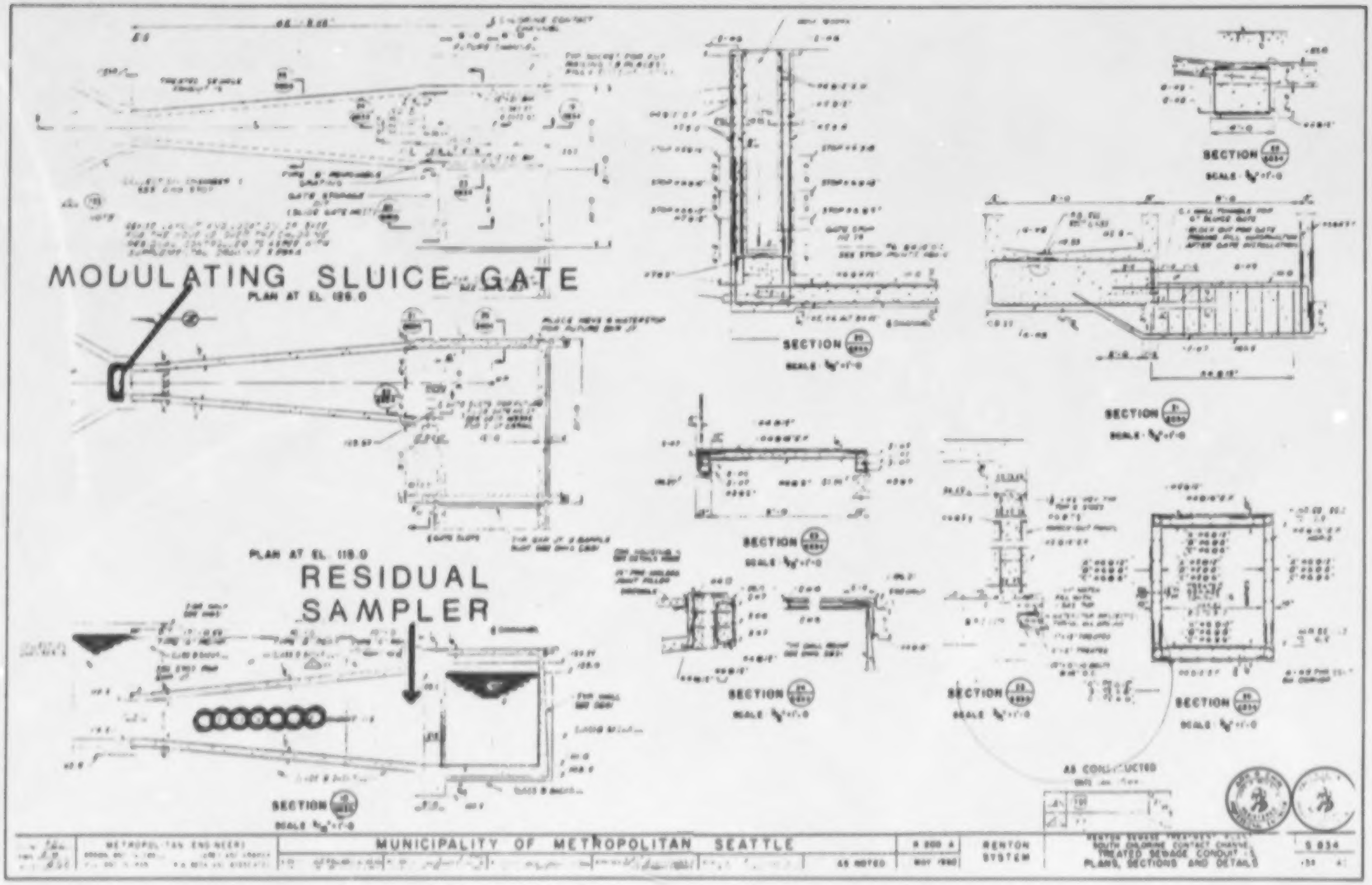
MODULATING SLUICE GATE
PLAN AT EL. 126.0
PLAN AT EL. 115.0
RESIDUAL SAMPLER
SECTION
SECTION
SECTION
SECTION
SECTION
SECTION
SECTION
AS CONSTRUCTED
MUNICIPALITY OF METROPOLITAN SEATTLE
METROPOLITAN ENGINEERS
AS NOTED
RENTON SYSTEM
TREATED SEWAGE CONDUIT
PLANS, SECTIONS AND DETAILS

FIGURE 10.4 LOCATION FOR CHLORINE RESIDUAL SAMPLER

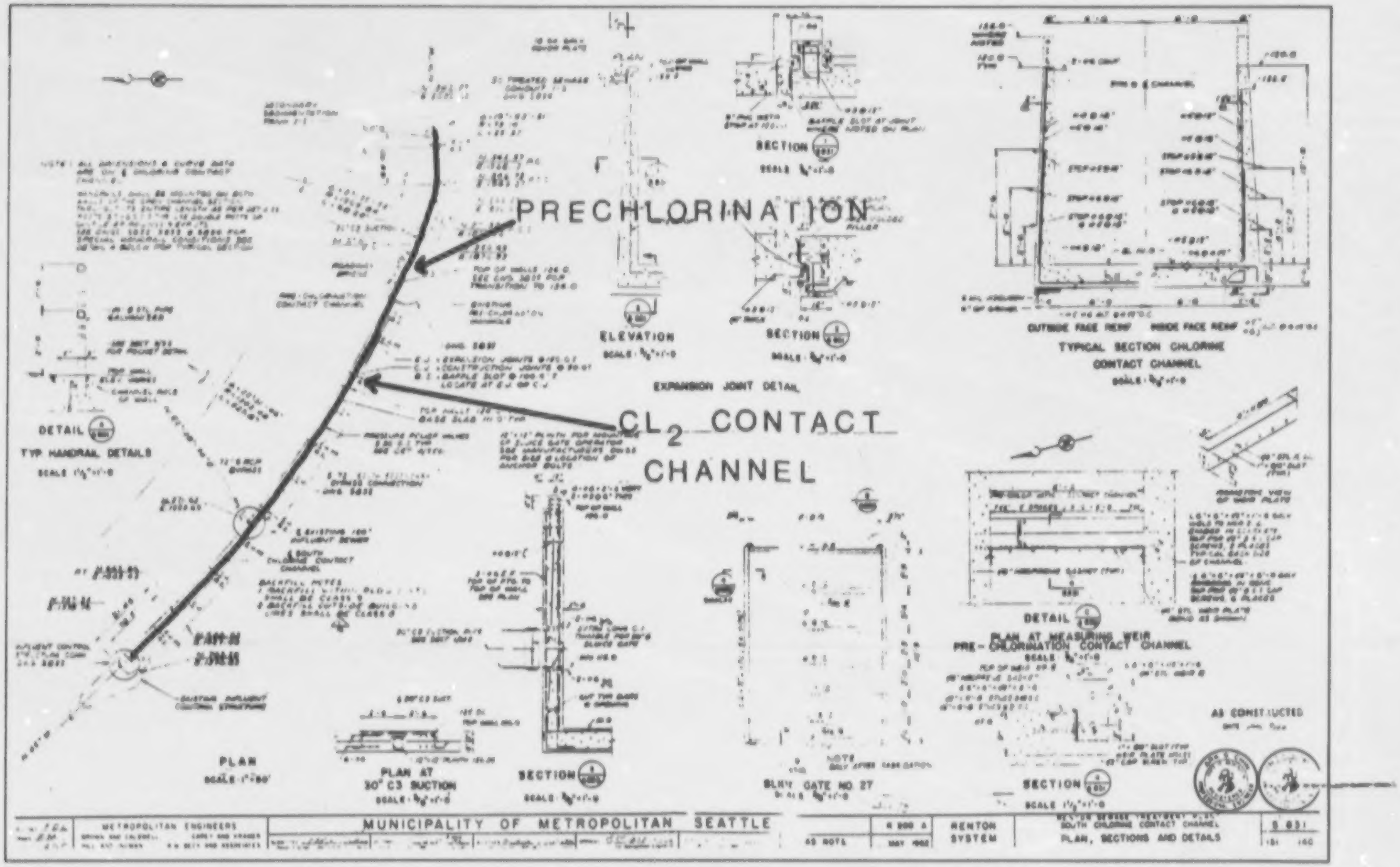
PRECHLORINATION
CL$_2$ CONTACT CHANNEL
DETAIL
TYP HANDRAIL DETAILS
PLAN
PLAN AT 30" C3 SUCTION
SECTION
ELEVATION
EXPANSION JOINT DETAIL
TYPICAL SECTION CHLORINE CONTACT CHANNEL
OUTSIDE FACE REINF
INSIDE FACE REINF
PLAN AT MEASURING WEIR PRE-CHLORINATION CONTACT CHANNEL
SLUICE GATE NO 27
AS CONSTRUCTED
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
RENTON SYSTEM
SOUTH CHLORINE CONTACT CHANNEL
PLAN, SECTIONS AND DETAILS

FIGURE 10.5 CHANNEL PROVIDES AMPLE CONTACT TIME

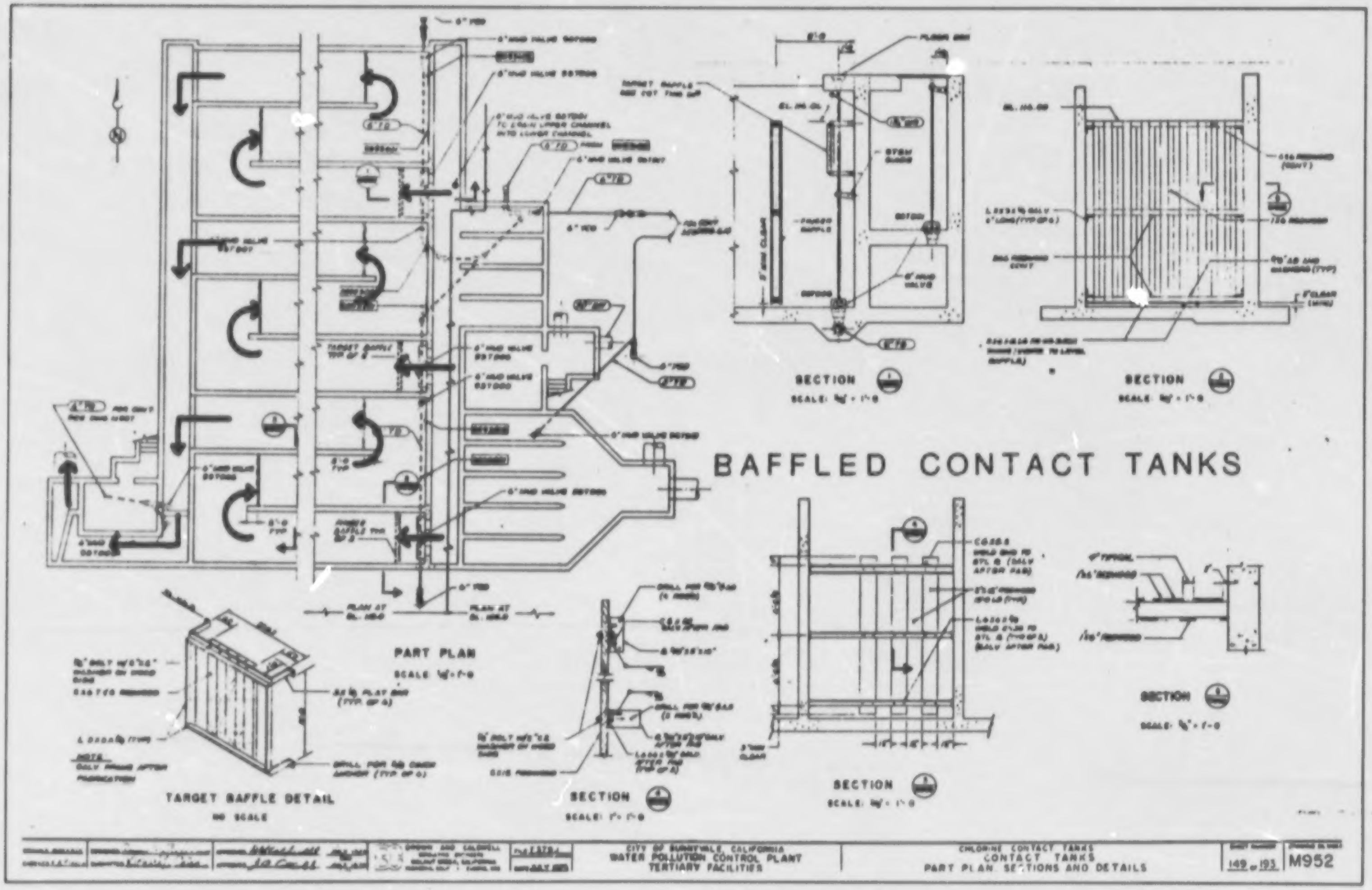
BAFFLED CONTACT TANKS
PART PLAN
TARGET BAFFLE DETAIL
NO SCALE
SECTION
SECTION
SECTION
SECTION
SECTION
CITY OF SUNNYVALE, CALIFORNIA
WATER POLLUTION CONTROL PLANT
TERTIARY FACILITIES
CHLORINE CONTACT TANKS
CONTACT TANKS
PART PLAN, SECTIONS AND DETAILS
149 of 195
M952

FIGURE 10.6 BAFFLES TO PREVENT SHORT CIRCUITING

UNIT PROCESS DESIGN - EFFLUENT DISCHARGE

UNIT 11

UNIT 11 - UNIT PROCESS DESIGN - EFFLUENT DISCHARGE

OBJECTIVES

At the conclusion of this presentation, the attendee should be able to:

- State the three principal means used to measure effluent flow.
- Identify at least three means of improving discharge effluent.
- Discuss the requirements relative to facility elevation.
- Design efficient diffusion systems.

UNIT 11 - UNIT PROCESS DESIGN - EFFLUENT DISCHARGE

A. Effluent Flow Measurement

There are three principal means by which final effluent flow is measured at wastewater treatment facilities. Flumes are used when effluent is discharged into a body of water that does not fluctuate in surface elevation (e.g., lakes). Otherwise, weirs are used to measure discharges. The latter are inexpensive and easy to install, calibrate and maintain (see Figure 11.1). For these reasons, weirs are often used at smaller facilities and package plants. Weir measurement of discharge is also adaptable to changes in plant flow. A weir can be enlarged or changed as plan flows increase. A third flow measurement technique utilizes orifices or pipe meters. However, these require full outfalls under all plant flow conditions.

B. Discharge Techniques

The type of discharge technique used is dependent upon location requirements, with many plants outfalling into streams that are at a lower elevation than the treatment facilities. To prevent the formation of foam, the outfall pipe should discharge beneath the surface of the receiving body. Foam can be further alleviated by placing the outfall pipe or channel on a slope of no more than 15 degrees from the horizontal. Finally, maintaining a vacuum in the outfall pipe will prevent freefall of the effluent and reduce the amount of entrained air, thus reducing foaming at the discharge point.

C. Elevation of Facility

Wastewater treatment plants should only be located high enough above a river or ocean outfall to provide adequate flood protection. If the facility is situated at an elevation that will insure gravity discharge at all flood stages, then the influent pumps will be providing excess head under normal flow conditions (see Figure 11.2). This will necessitate larger pumps and greater energy requirements over those which would be needed if the plant were at a lower elevation. Discharge structures should be designed so that gravity flow is used to discharge final effluent under average flow conditions. If flood stage is above normal discharge stage, effluent pumps can be used to overcome this head and insure continued flow of treated wastewater.

D. Discharge Diffusion

When the discharge exceeds allowable concentrations of persistent toxic materials, consideration should be given to whether substances that are harmful in high concentrations are acceptable at low concentrations. A diffuser located at the end of an outfall pipe can be used to mix the

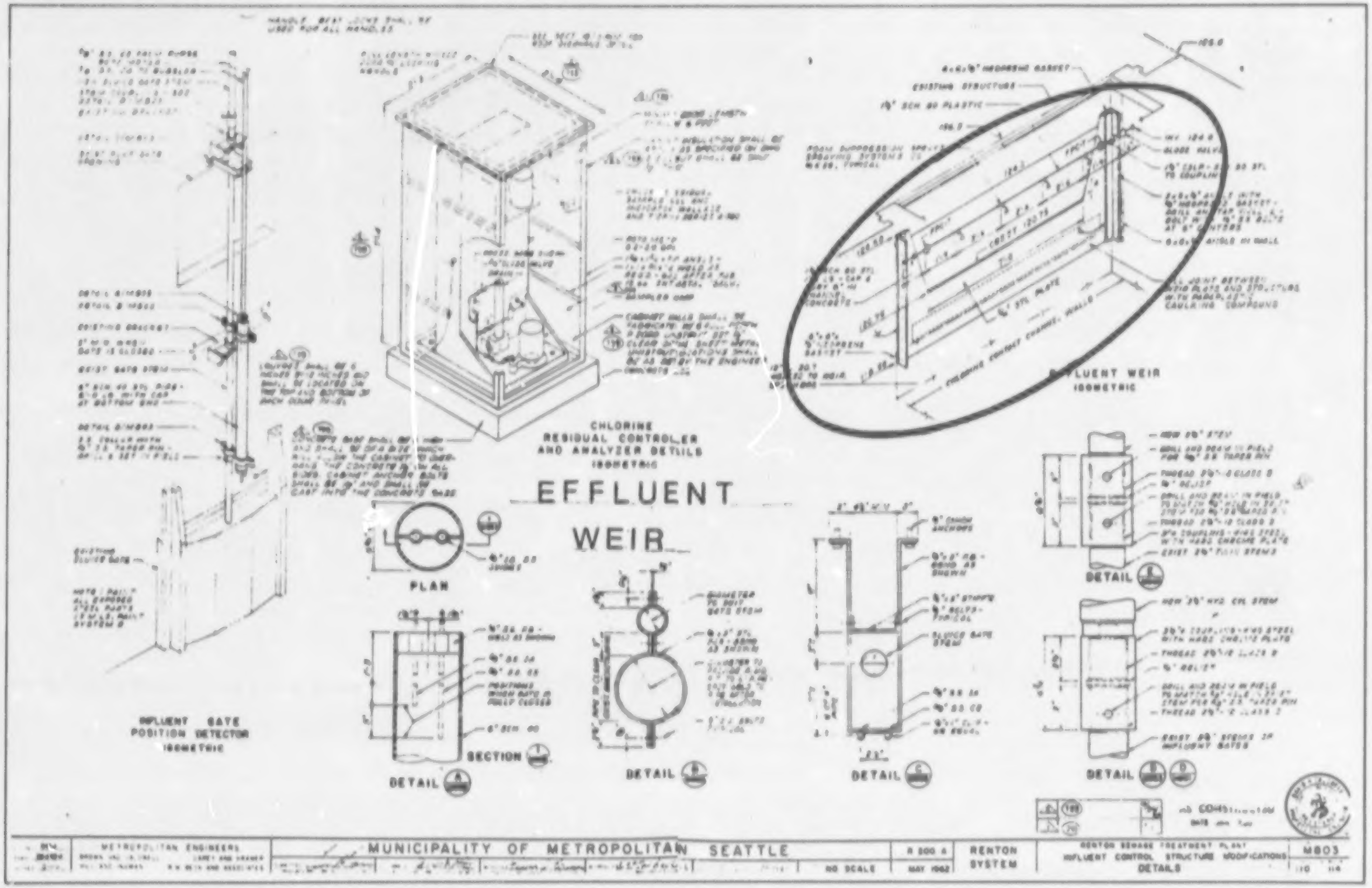
EFFLUENT GATE POSITION DETECTOR ISOMETRIC
CHLORINE RESIDUAL CONTROLER AND ANALYZER DETAILS ISOMETRIC
EFFLUENT WEIR ISOMETRIC
EFFLUENT WEIR
PLAN
SECTION
DETAIL
DETAIL
DETAIL
DETAIL
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
NO SCALE
MAY 1962
RENTON SYSTEM
RENTON SEWAGE TREATMENT PLANT
INFLUENT CONTROL STRUCTURE MODIFICATIONS
DETAILS
MB03

FIGURE 11.1 EFFLUENT MEASUREMENT WEIR

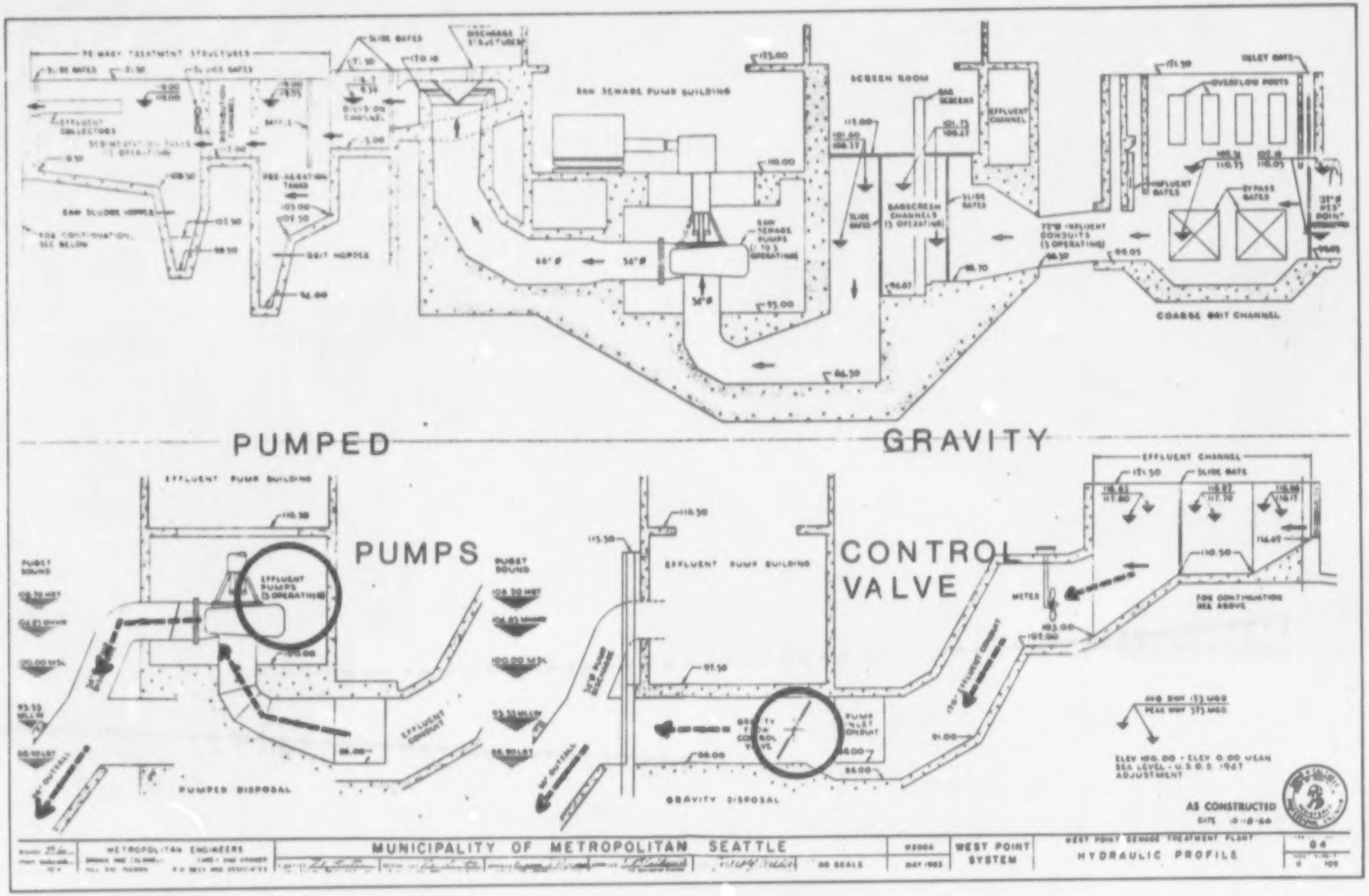
PUMPED
GRAVITY
PUMPS
CONTROL VALVE
RAW SEWAGE PUMP BUILDING
SCREEN ROOM
EFFLUENT CHANNEL
COARSE GRIT CHANNEL
EFFLUENT PUMP BUILDING
PUGET SOUND
PUMPED DISPOSAL
GRAVITY DISPOSAL
AVG DWF 125 MGD
PEAK DWF 325 MGD
ELEV 100.00 = ELEV 0.00 MEAN SEA LEVEL - U.S.C.G.S. 1947 ADJUSTMENT
AS CONSTRUCTED
DATE 10-18-66
METROPOLITAN ENGINEERS
MUNICIPALITY OF METROPOLITAN SEATTLE
NO SCALE
MAY 1963
WEST POINT SYSTEM
WEST POINT SEWAGE TREATMENT PLANT
HYDRAULIC PROFILE
G4

FIGURE 11.2 UTILIZATION OF GRAVITY OR PUMP DISCHARGE AND INFLOW

wastewater with the ambient water in order to disperse potentially harmful substances (see Figure 11.3). The outfall pipe transports the effluent to a point in the receiving water where mixing can occur (e.g., the center of a stream). At this point, the diffuser discharges the wastewater into the receiving body.

Diffusers use the momentum of the wastewater flow and the density differences between the effluent and the receiving water to maximize mixing. Thus, the designer should locate the diffuser along a stream bottom using horizontal jets to take full advantage of both of these factors (see Figure 11.4).

The flow rate out of individual ports should be uniform along the entire length of the diffuser to maximize mixing. This can be approximated by making the ports near the entrance smaller than those near the end. Flow velocities in all parts of a diffuser should be 2 to 3 feet per second at peak flow to prevent deposition of solids and intrusion of ambient water into the pipe. This condition may be achieved by reducing the size of the pipe as distance from the entrance increases (see Figure 11.5). The discharge velocity out of the ports should be greater than the internal flow velocity inside the diffuser. Therefore, the sum of all port areas downstream of any point in the diffuser must be less than the diffuser pipe area. In general, the sum of all diffuser port areas should not be greater than 1/2 to 1/3 the pipe area in that location.

Outlet ports should be simple in design with no protrusions to entrain debris. If nozzles are used, they should be easily replaceable. The inside of all ports should be bell-mouthed to prevent clogging. If ports are placed on both sides of the pipe, their locations should be alternated to prevent flow instabilities or oscillations. A flap gate located at the end of the diffuser pipe will make maintenance of the pipe easier.

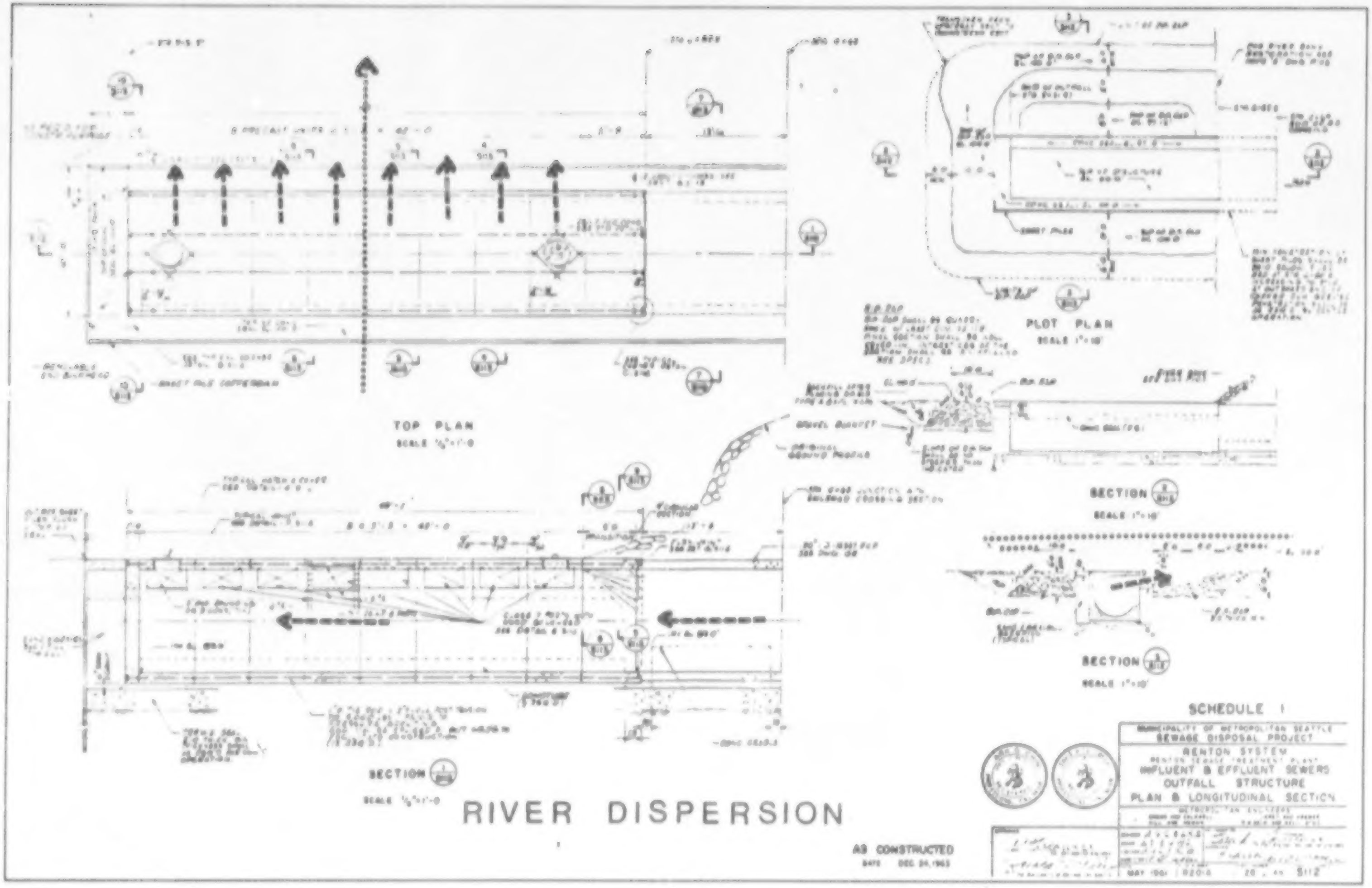
TOP PLAN
PLOT PLAN
SECTION
SECTION
SECTION
SCHEDULE 1
MUNICIPALITY OF METROPOLITAN SEATTLE
SEWAGE DISPOSAL PROJECT
RENTON SYSTEM
RENTON SEWAGE TREATMENT PLANT
INFLUENT & EFFLUENT SEWERS
OUTFALL STRUCTURE
PLAN & LONGITUDINAL SECTION
RIVER DISPERSION
AS CONSTRUCTED
DEC 24, 1963
MAY 1961
5112

FIGURE 11.3 EFFLUENT DIFFUSER

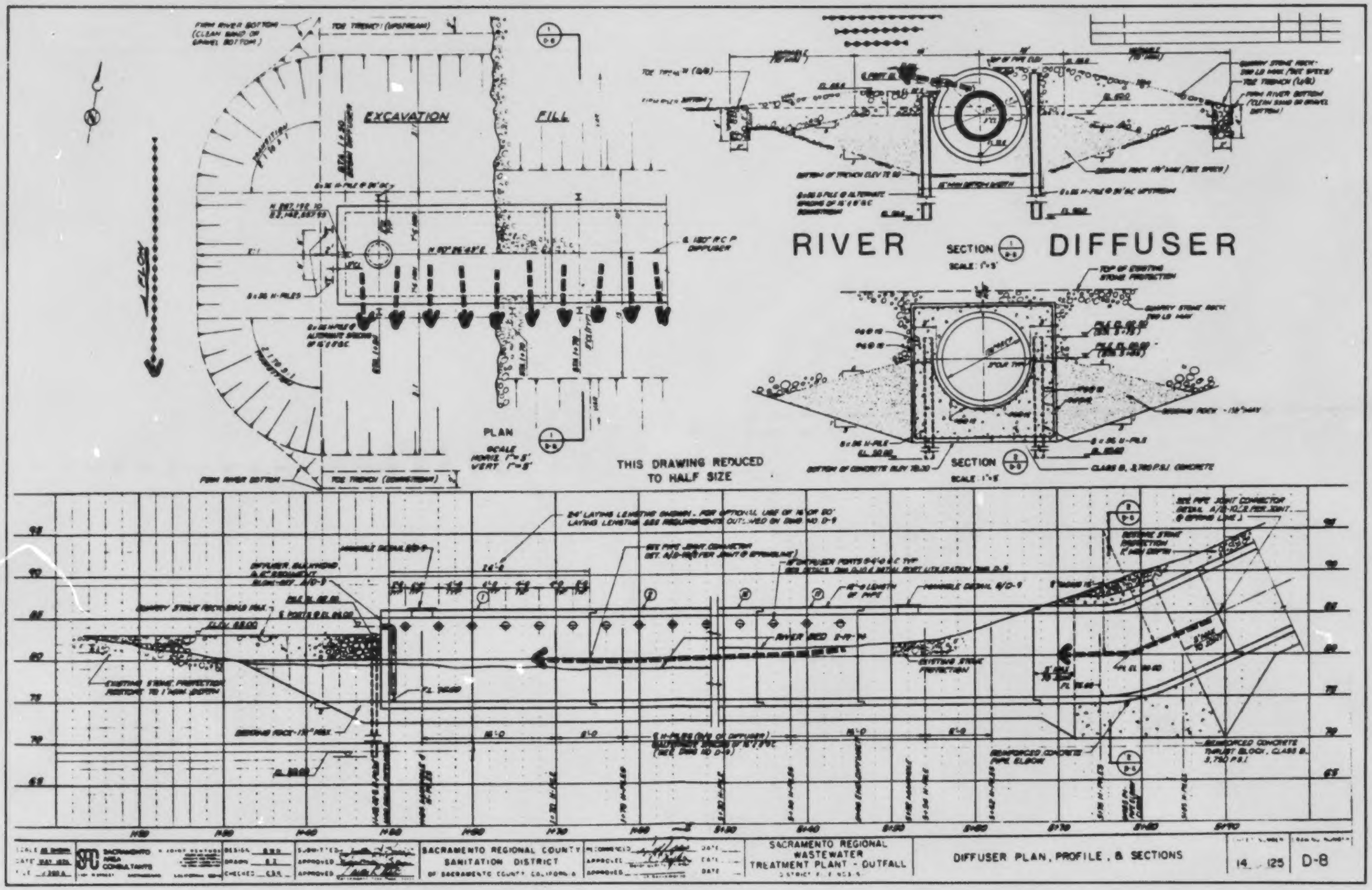
EXCAVATION
FILL
FLOW
PLAN
THIS DRAWING REDUCED TO HALF SIZE
RIVER
SECTION
DIFFUSER
SECTION
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT - OUTFALL
DIFFUSER PLAN, PROFILE, & SECTIONS
D-8

FIGURE 11.4 DIFFUSER PLACEMENT ON RIVER BOTTOM

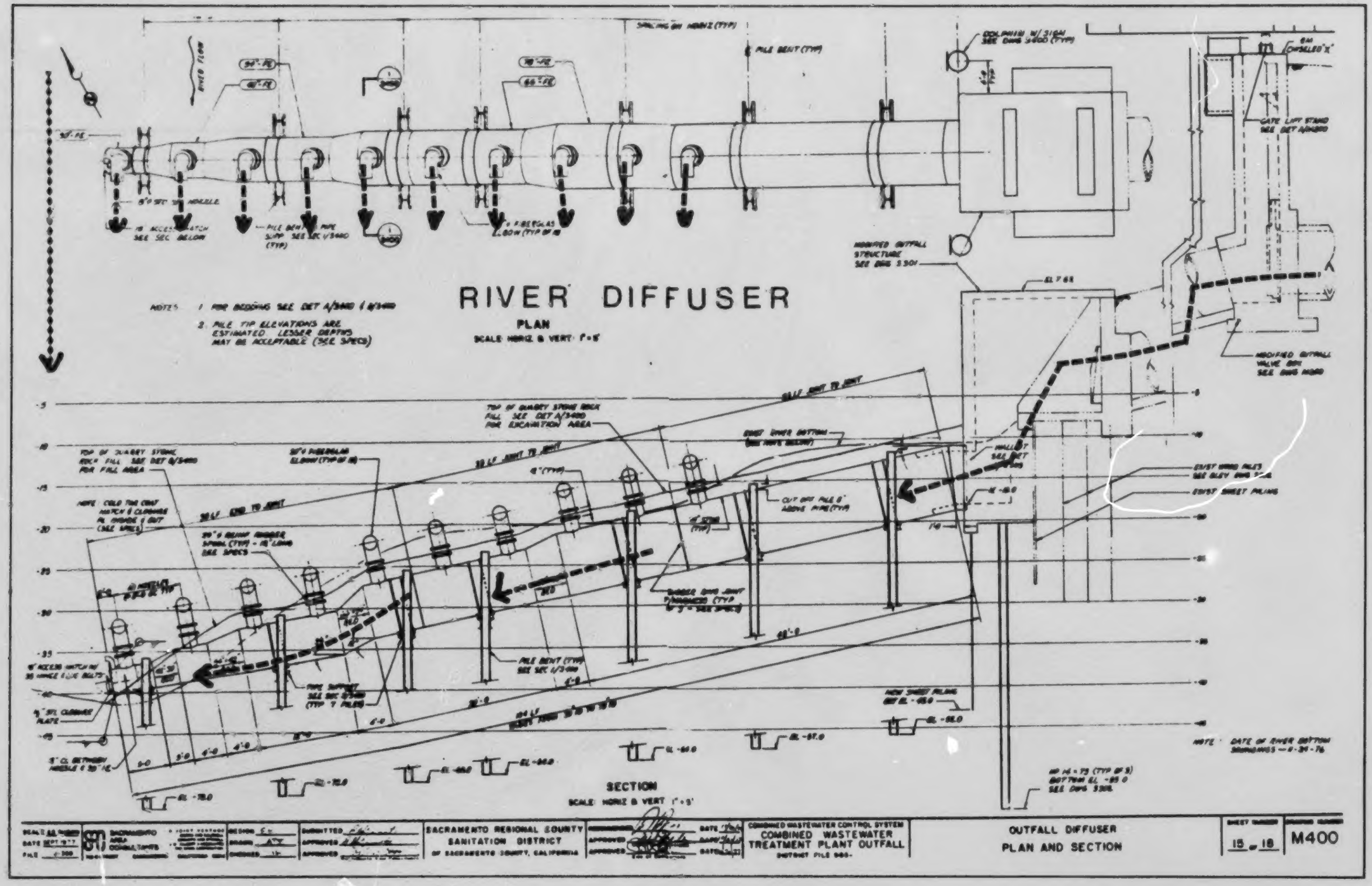
RIVER DIFFUSER
PLAN
SCALE HORIZ & VERT 1" = 5'
NOTES 1 FOR BEDDING SEE DET A/3400 & B/3400
2. PILE TIP ELEVATIONS ARE ESTIMATED LESSER DEPTHS MAY BE ACCEPTABLE (SEE SPECS)
SECTION
SCALE HORIZ & VERT 1" = 5'
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
COMBINED WASTEWATER CONTROL SYSTEM
COMBINED WASTEWATER TREATMENT PLANT OUTFALL
OUTFALL DIFFUSER
PLAN AND SECTION
15 of 18
M400

FIGURE 11.5 PORT DISTRIBUTION ON DIFFUSER

UNIT PROCESS DESIGN - SLUDGE TREATMENT

UNIT 12

UNIT 12 - UNIT PROCESS DESIGN - SLUDGE TREATMENT

OBJECTIVES

At the conclusion of this presentation, the attendee should be able to:

- Define primary and secondary sludges.
- Define appropriate sludge piping.
- Identify appropriate sludge system instrumentation.
- Discuss efficient means for sludge thickening and dewatering.
- Identify and discuss various designs which enhance dissolved air floatation.
- Discuss centrifugal thickening and identify numerous "design hints."
- List and discuss various sludge stabilization techniques and efficient system designs.
- Discuss vacuum filtration as a design option.
- Design floating covers.
- Identify three types of heat exchanger options and heating engines.
- Discuss sludge fueling and withdrawal.
- List three "design hints" to enhance gas production and utilization control.
- Design an effective aerobic digestion system that utilizes "design hints."
- Identify critical areas in sludge conveyance design and various options to enhance operation.

UNIT 12 - UNIT PROCESS DESIGN - SLUDGE TREATMENT

I. INTRODUCTION

Solids are produced at nearly every step in the wastewater treatment process. These include screenings, grit, and primary and secondary sludges. The disposal of these by-products constitutes a challenge for the Design Engineer. The solids, taken together, contain all of the components of raw sewage. Putrescible organic solids are the major component of primary sludge. Secondary sludge solids are the soluble organic matter found in wastewater converted into microbial biomass. Sludge, especially secondary sludge, concentrates toxic compounds, human enteric viruses and other pathogens. Additionally, the biological treatment process results in the production of large quantities of secondary sludge (an average of 19,400 gallons of sludge/million gallons of sewage), and this sludge is nearly 99 percent water. Thus, the engineer is faced with disposing of a large quantity of putrescible material that is not only offensive, but also poses a health hazard.

Surveys of wastewater treatment plant deficiencies (e.g., Smith and Daigh, 1981) have shown that sludge handling facilities are often deficient in design, or their operation is misunderstood by plant personnel. Thus, it behooves the designer to carefully consider the sludge management plan to make certain that the facilities are adequate to handle the solids generated at the treatment plant. The designer must be sure that the operation and maintenance of sludge treatment processes are understood clearly by personnel and can be carried out easily in day to day operation.

A. Piping and Instrumentation

The sludge piping system should have isolation valves to allow for equipment or metering repairs. Provisions should be made for cleaning, draining and flushing sludge piping. Flanged tees and crosses and cleanouts to allow rodding of suction lines are desirable. Provisions for backflushing with positive displacement pump discharges are desirable. Provisions for cleaning by hot water, steam injection or chemical degreasing should be considered in long lines containing raw sludge or scum. In cold climates, shallow sludge pipes can freeze and become clogged. This situation can be alleviated by connecting a compressed air line to these pipes, thus enabling the operator to empty the line with a blast of air. Sludge grinders should be considered where downstream process equipment such as centrifuges, heat exchangers or sludge mixing devices are susceptible to trash or rag buildup.

Accurate and reliable monitoring and control of sludge streams and processes are more difficult than monitoring and controlling wastewater streams. Debris, gases, high viscosity and grit all tend to interfere with instrument performance. Frequent maintenance and calibration is essential for

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most sludge measurement instrumentation. Redundancy of sensors may be necessary to obtain reliable readings. Sludge density meters and flowmeters should be installed to insure that the section of piping containing the sensor has full pipe flow and not open channel flow. Pressure gauges with non-clog diaphragms should be used in most cases to avoid errors due to sludge deposition and solidification. Care should be given so that thermocouples are not located in stagnant or dead zone areas of tanks and pipelines. Turbidity may be useful to monitor supernatant and recycle streams from sludge handling processes as an early warning of significant solids losses. Reliable sludge measurements are important since an inefficient sludge handling process can cause a detrimental effect on the entire treatment plant. The designer and the operator should give careful consideration to the design, calibration, maintenance and interpretation of sludge measuring devices.

B. Sludge Thickening and Dewatering

The purpose of sludge thickening and dewatering is to reduce the volume of waste sludges prior to either final disposal or other treatment processes. There are four methods that are generally employed to thicken sludges. They are: gravitational thickeners, dissolved air floatation, centrifugal thickening and vacuum filtration. Each of these utilizes a different principle to achieve sludge volume reduction. The theory and process design of each type of thickening method are detailed elsewhere. Therefore, this discussion will center on design characteristics that affect the operation and maintenance of sludge thickening devices.

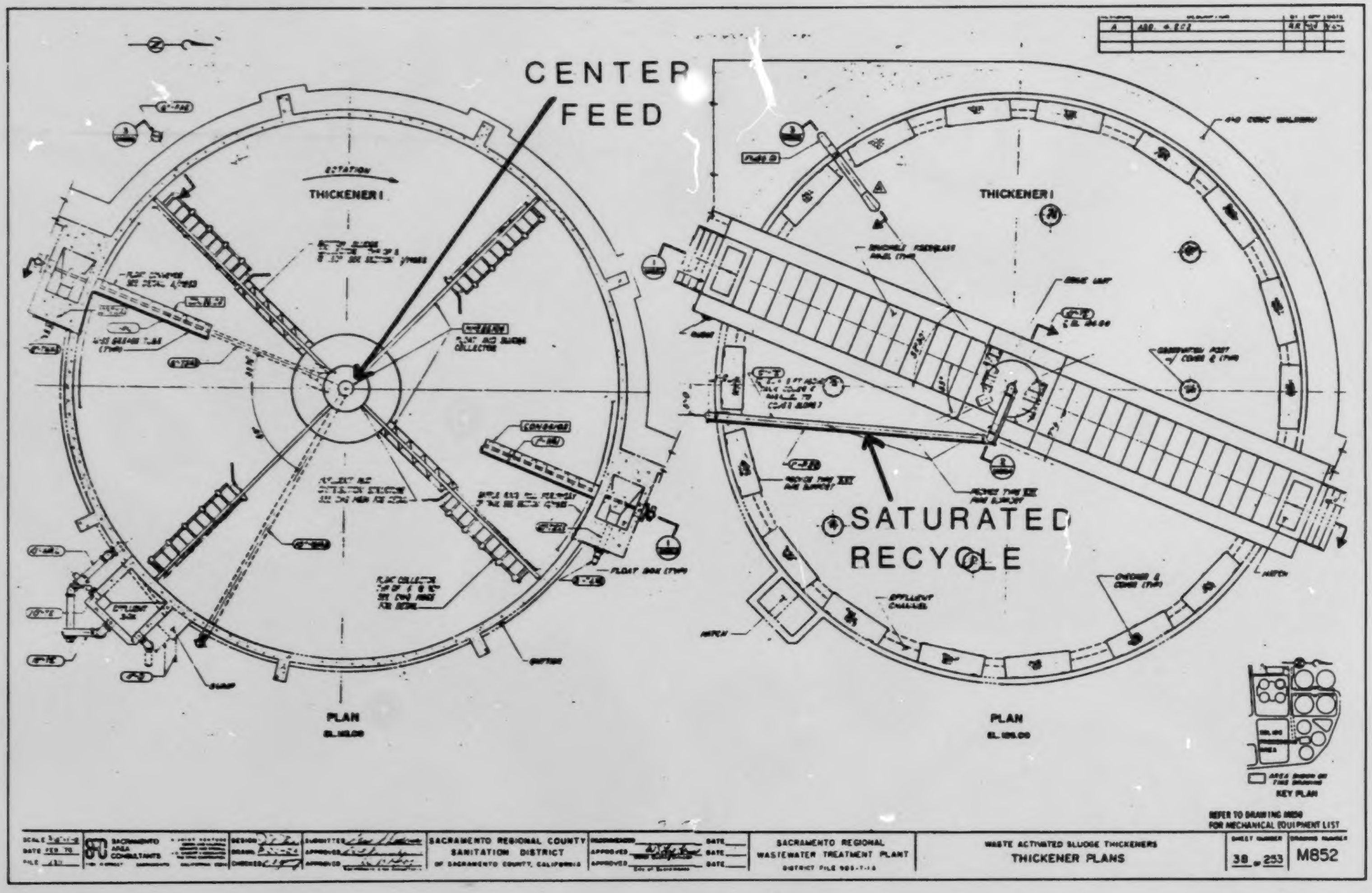
1. Gravitational Thickening

a. Tank Shape

This process uses the force of gravity to reduce the volume of sludge generated at wastewater treatment plants. These thickeners are designed on the basis of hydraulic surface loading and solids loading. Therefore, the principles that apply are the same as those used in sedimentation tanks.

Both circular and rectangular tanks are used as gravity thickeners. However, circular tanks have some advantages over rectangular tanks (see Figure 12.1). The sludge is delivered continuously to the point of drawoff in a circular thickener, but only intermittently in a rectangular tank. In the former unit, it is relatively easy to maintain a substantial sludge depth in the areas of sludge withdrawal and avoid "rat holing." In a rectangular unit this is more difficult. However, rectangular tanks utilize less area than circular units, and thus may be more appropriate at plants where land area is limiting. Sludge withdrawal pumps can be located close to rectangular tanks. This can help alleviate pipe clogging problems. Sludge is collected in circular units using mechanical collector arms while rectangular tanks employ travelling flights to remove thickened sludge.

Circular thickeners should be designed with relatively steep bottom slopes (1.5 to 3 inches/foot). This will enhance the movement of solids into the withdrawal zone. The steep slope helps prevent dilute


CENTER FEED
SATURATED RECYCLE
ROTATION
THICKENER I
THICKENER I
PLAN
PLAN
KEY PLAN
REFER TO DRAWING M850 FOR MECHANICAL EQUIPMENT LIST
SACRAMENTO AREA CONSULTANTS
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
WASTE ACTIVATED SLUDGE THICKENERS
THICKENER PLANS
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M852

FIGURE 12.1 CIRCULAR SLUDGE THICKENERS

underflow sludge concentrations which can result if there is a dilute suspension in the drawdown zone. Finally, steeper slopes reduce the time sludge remains in the thickener, and thus lessen the problems associated with biodegradation of the material.

The design of rectangular thickeners should incorporate a mechanism for lateral or transverse movement of solids to the withdrawal point or points, and the hopper should be deep enough to ensure that "rat holing" will not occur. The machine itself must be strong enough to handle the added load derived by the necessity to heap sludge in the vicinity of the point of withdrawal. The most common problems associated with rectangular thickener operations are "rat holing" and machine breakage.

b. Design Considerations

Wastewater treatment plants often employ combined primary/secondary sludge thickening. If combined thickening is practiced, the waste activated sludge line should be relatively long and the primary sludge line should be relatively short. These lines are then joined and become a common thickener feed line.

The design of the thickener feed mechanism should minimize turbulence in the feedwells. By employing bottom feed inlets to the feedwell, feed sludge will flow vertically and then laterally with low turbulence. Tangential entries or opposing tangential feed entries through a tee connection are preferred over a system that directs the feed vertically downward. A horizontal feed entry located just under the surface of the liquid and directed toward the center of the thickener feedwell generally will produce satisfactory results. Air entrainment in the feed entry should be avoided to reduce froth formation on the thickener surface.

Sludge rakes may be exposed to considerable resistance to movement due to drag and accumulations on the rakes. Sufficient torque must be designed into the system, both in the structure of the rake mechanism and in the gearing and motor utilized to drive the unit to overcome these forces. The normal operating torque in a thickener should not exceed 10 percent of the rated or maximum torque value. The rated torque should be set high enough to provide sufficient driving force to the mechanism to get out of trouble when required. Continuous operation at torques greater than 40 to 50 percent of the rated capacity of the mechanism will result in greatly shortened operating life of the gears and bearings.

Some treatment plants have been designed to pump scum collected on all unit processes to the sludge thickeners. This may cause an accumulation of this material in the thickener feedwell and cleaning problems will result. It is recommended that all scum be pumped to a decant tank. The overflow is sent to final disposal and underflow is returned to the primary or secondary treatment processes.

Continuous withdrawal of thickener underflow will result in the most effective thickener operation. If intermittent withdrawal is necessary, then this is best done using a timer which operates the sludge pumps for short intervals on a frequent basis. This is preferable to running them for longer periods once or twice a shift.

The preferred sludge pumps are plunger-type positive displacement pumps fitted with double-inlet valves. Progressing cavity pumps can be used if sufficient degritting equipment has been provided to minimize wear. Multiple pumps or variable-speed pumps are desirable to allow removal at the correct rate and to provide good inventory control.

Underflow suction piping between the thickener discharge cone and the inlet of the pump should be as short as possible. The piping should be provided with adequate access points for cleanout. If access will be a problem, the piping should be placed in a gallery. Provide access for snaking to the sludge well and to the pumps. Dual sludge lines are suggested if plugging is anticipated. For operation and maintenance purposes, the underflow pump should be located at the side of the thickener at an elevation below the water level in the thickener to ensure that the suction is always flooded.

Maintaining a balance between solids input and output is necessary for good overall thickener operation. Design should include a means for determining sludge blanket level as well as the ability to sample and monitor solids concentrations in the supernatant stream.

Consideration should be given to the location of gravity thickeners within the wastewater treatment facility. For convenience and operational efficiency, a thickener can be located within a cluster of clarifiers. In cases where grit removal may best be carried out at the thickener, grit-handling facilities, including the degritting unit, storage bins, and vehicle access should be located at the thickener site. Access for tank trucks should be located close to thickeners in the event that the dewatering equipment is out of service. To minimize complaints from odor problems or aesthetic unsightliness, thickeners should be located where they will receive frequent operational attention but far enough from plant boundaries to shield them from casual observation.

2. Dissolved Air Flotation

Dissolved air flotation (DAF) uses fine gas bubbles to buoy up sludge solids that are in suspension and raise them to the liquid surface, thereby reducing the water content of the solids. The solids/gas matrix is then removed by mechanical means. Heavier solids not entrapped by the gas bubbles settle to the bottom of the tank and are removed. The supernatant is withdrawn and recycled back into the treatment plant.

a. Methods of Dissolved Air Flotation

There are three principal types of flotation processes. In the diffused or induced air flotation process, the air is introduced at atmospheric pressure. Turbulence is used to shear the air into small bubbles which are entrapped in the solids and rise to the surface. The dissolved air flotation process may use either vacuum or pressure cycles to dissolve and release air from solution. In the vacuum flotation process, the liquid is saturated at atmospheric pressure and a vacuum is applied to release the dissolved gas. This process is not used widely because of the amount of air that can be applied to the wastewater. Pressurized flotation uses several atmospheres of pressure to increase the amount of air that can be released upon pressure let-down.

Pressurized, dissolved air flotation may use different contacting patterns to maximize air input and minimize shearing of the solids. In direct pressurization, the entire flow is pressurized to allow large amounts of air input. The major disadvantage of this approach is that the solids and floc particles are subjected to shear forces during pressure release. Using split treatment, only a portion of the flow is pressurized and subjected to the shear forces during pressure release. This approach limits the amount of air which can be put into the wastewater. Pressurization and recycling of clarified effluent minimizes the shearing of flocs and solids. With variable recycle, any amount of air can be applied. Because of its flexibility, variable recycle is the most commonly used form of dissolved air flotation.

b. Operational Considerations

Both circular and rectangular DAF tanks are employed. Rectangular units are preferred at treatment plants where space is at a premium. However, circular tanks can be built to handle larger solids and hydraulic loads than can rectangular tanks (see Figure 12.2).

The capacity of flotation thickeners is much greater than gravity units. For this reason, an equivalent amount of thickening capacity can be constructed in a much smaller space using DAF. Thus, flotation thickeners can often be placed in buildings. This is desirable in some climates where heavy rains or extended cold periods can interfere with thickener performance.

Surface skimmers are used to remove the solid/gas matrix, or "float," from the surface of the tank and maintain a constant blanket depth (see Figure 12.3). Skimmers can be operated using either manual or automatic control, but the latter is preferable. By using automatic timers, the float blanket can be kept from 12 to 18 inches deep. This will maximize both float drainage and float solids concentration. Flexibility in skimmer operation should be provided by the Design Engineer. The skimmers should be capable of variable speeds of up to 25 ft/min. Adjusting the depth of the skimmers will enable the operator to optimize float thickness.

Floor rakes are used to remove settled solids from the floor of the thickener. The rakes should be designed to operate independently of the surface skimmer. Thus, the operator will have to use the floor rakes only as required.

The overflow weir controls the liquid level within the flotation tank with respect to the float collection box. Therefore, the

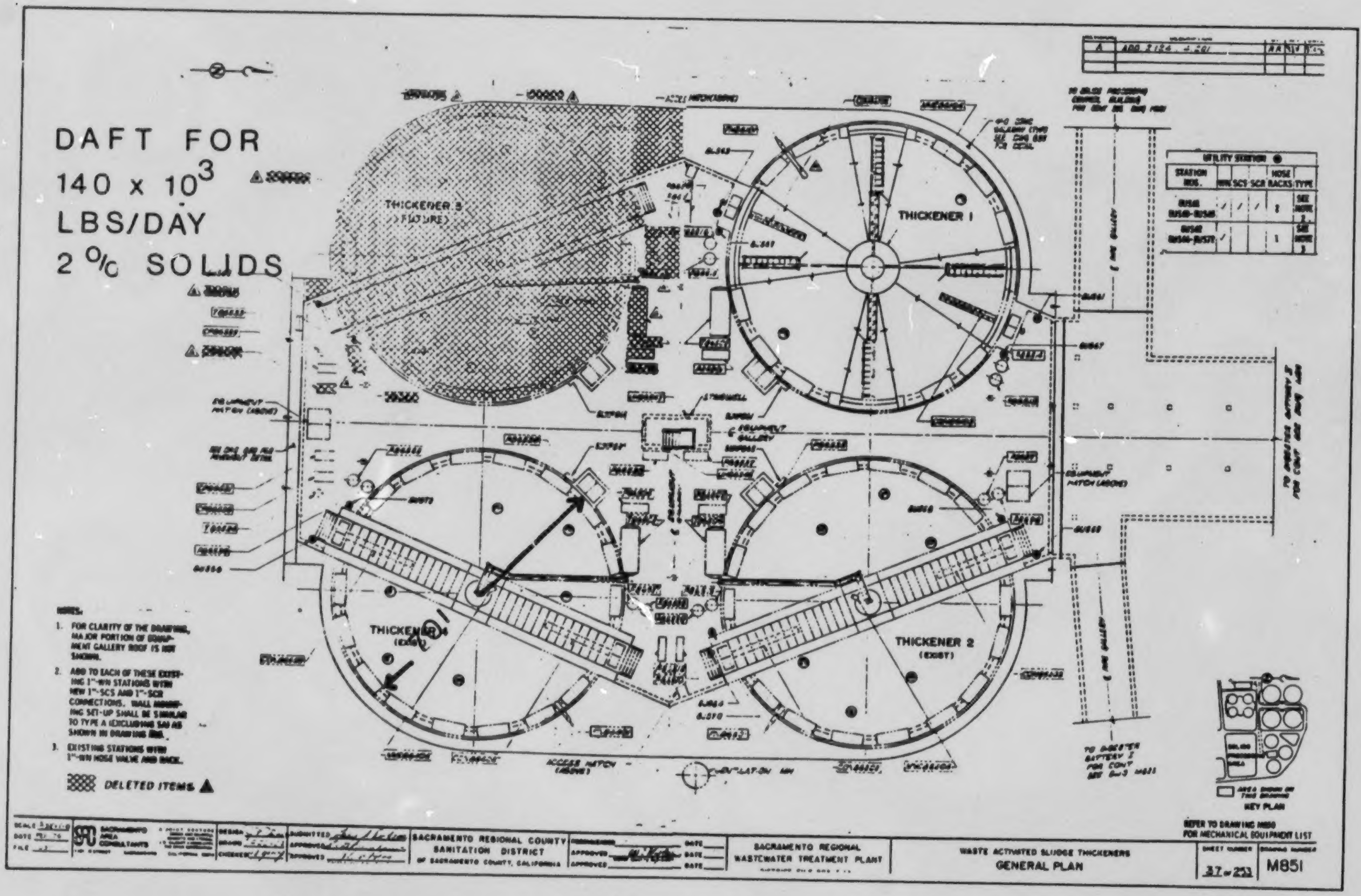
DAFT FOR
140 x 10^3
LBS/DAY
2 % SOLIDS
THICKENER 3 (FUTURE)
THICKENER 1
THICKENER 4 (EXIST)
THICKENER 2 (EXIST)
UTILITY STATION
NOTES:
1. FOR CLARITY OF THE DRAWING, MAJOR PORTION OF EQUIPMENT GALLERY ROOF IS NOT SHOWN.
2. ADD TO EACH OF THESE EXISTING 1"-WN STATIONS WITH NEW 1"-SCS AND 1"-SCR CONNECTIONS. WALL MOUNTING SET-UP SHALL BE SIMILAR TO TYPE A (EXCLUDING SAU) AS SHOWN IN DRAWING
3. EXISTING STATIONS WITH 1"-WN HOSE VALVE AND RACK.
DELETED ITEMS ▲
KEY PLAN
ACCESS HATCH
EQUIPMENT GALLERY
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
WASTE ACTIVATED SLUDGE THICKENERS
GENERAL PLAN
M851

FIGURE 12.2 CIRCULAR TANKS FOR HANDLING LARGE SOLIDS AND HYDRAULIC LOADS

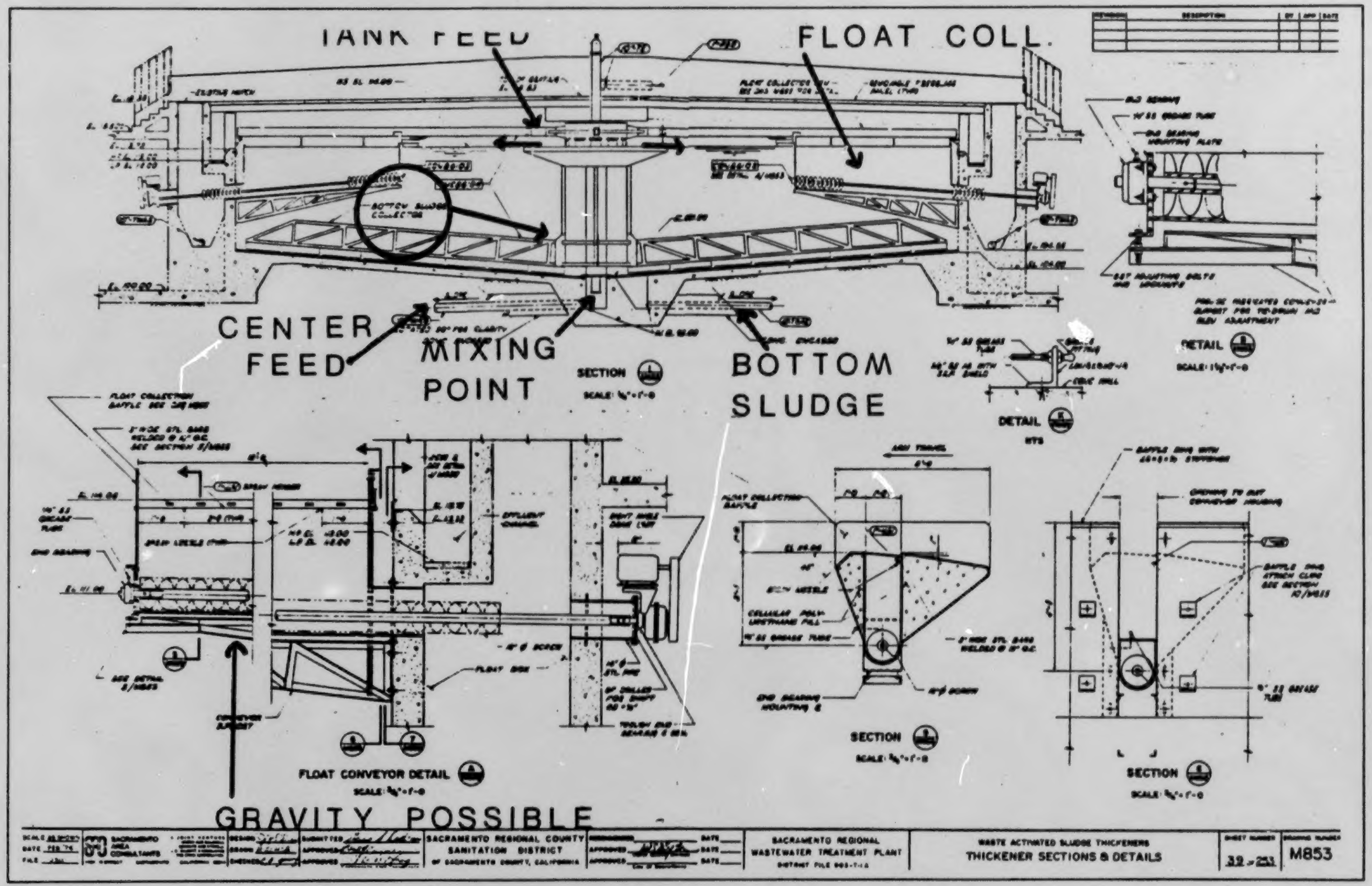
TANK FEED
FLOAT COLL.
BOTTOM SLUDGE COLLECTOR
CENTER FEED
MIXING POINT
BOTTOM SLUDGE
SECTION
DETAIL
FLOAT CONVEYOR DETAIL
GRAVITY POSSIBLE
SACRAMENTO AREA CONSULTANTS
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
WASTE ACTIVATED SLUDGE THICKENERS
THICKENER SECTIONS & DETAILS
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FIGURE 12.3 SURFACE SKIMMERS IN DIRECT AIR FLOATATION (DAF) TANKS

position of the weir regulates the capacity and performance of the DAF unit. To insure maximum capacity and performance under fluctuating conditions, the weirs should be adjustable. Overflow rates from 1.0 to 0.4 gal/ft^2/day are commonly used. With a constant air-to-solids ratio, the performance of a unit will improve with decreasing overflow rate. Retention times in flotation tanks range from 10 to 60 minutes, depending on the application. Performance improves with increasing retention times.

The air-to-solids ratio is a measure of the amount of air applied per mass of solids in the wastewater. The optimum ratio is best determined from laboratory or pilot tests. The air-to-solids ratio is a function of the recycle flow rate, the operating pressure, and the efficiency of the saturation drum. By providing flexibility in recycle flow rate and pressure, the designer can enable the operator to be able to adjust readily to changes in influent wastewater or sludge. Solids capture is maximized by using liquid overflow for dissolution recycle. However, the system should have the flexibility to use plant secondary effluent for dissolution liquid if DAF overflow becomes overloaded with solids.

The pressurized recycle should be injected into the sludge stream prior to the stream entering the flotation tank. The air impregnated sludge should then be brought into the tank at the liquid surface. Otherwise, subsurface agitation may be created which can disturb the sludge layer on the tank bottom. The specific gravity of air/sludge mixture should be maintained between 0.6 and 0.7 to keep the material floating and increase the solids content of the mat.

The pressurization tank should be located adjacent to the DAF tank and pressurization pump to minimize liquid pumping requirements and head loss. The pressurization tank should be equipped with steel legs, a drainage opening, an access manhold for inspection and maintenance, a liquid level sight glass, and a pressure gauge and pressure release safety valve.

Other provisions for flexibility of operation that should be considered include: accurate flow splitting for multiple flotation units, a method for determining float concentration, a means for sampling the effluent stream solids load that is recycled to the head of the plant, variable flow rate control of the pressurized stream and the influent sludge stream, variable air pressure control for the pressurized stream, and effective moisture removal on the instrument air system if pneumatic controls are employed.

3. Centrifugal Thickening

Centrifugal thickening uses centrifugal force to separate sludge solids from wastewater. The force used is 500 to 3000 times that of gravity and the distance required for separation is relatively short. This means that centrifuges have high capacities and small space requirements when compared to gravity thickeners. The three types of centrifuges commonly used to process waste sludge are the imperforate basket, the disk-nozzle and the solid-bowl conveyor.

a. Centrifuge Requirements

Wastewater treatment plants normally require one standby centrifuge in a small installation and approximately 25 percent standby capacity in larger installations with many units. Ideally, centrifuges should be sized such that two or three can handle the projected load. Imperforate basket centrifuges are found most often in smaller treatment plants that require from two to six units.

The availability of sludge influences selection of the type of centrifuge needed. Some plants waste excess activated sludge continuously, whereas others waste it intermittently because disk centrifuges generally require cleaning after shutdown to prevent sludge from drying in nozzles and plugging them. Therefore, intermittent wasting of sludge with short periods of operation particularly favors conveyor or basket centrifuges. In some plants where the daily sludge may vary considerably in character, where dewatering or thickening may alternate at different times, or where several varieties of sludge must be dealt with, the flexibility inherent in the type of centrifuge selected is also important. On abrasive sludges, the imperforate basket centrifuge shows little wear even when sludges contain a considerable quantity of sand, as is common in coastal plants. These units are effective on industrial waste that may include metal precipitates or flocculent sludges of differing types.

b. Operational Considerations

Centrifuges should be supported on piers and/or elevated concrete or steel platforms to allow free discharge of both supernatant and thickened sludge. The platforms should provide an inertia loading support 2.0 times the equipment weight vertically and 1.5 times the weight horizontally. Feed piping and effluent discharge connections should be flexible and cake chutes should not be fastened rigidly to receivers. Isolators should be installed to dampen the transmission of vibrations from the machine to the supporting structure.

Generally, centrifuges operate at noise levels of 80 to 90 dbA measured at 3 feet from the machine. This noise will be amplified if the ceiling of the room is low or hard or if hard walls are close to the centrifuge. Such sound-reflecting surfaces should be covered with acoustically absorbing material. Additionally, operator stations should be isolated from the centrifuge room to avoid the excessively noisy environment.

To accommodate major maintenance of the centrifuge, overhead lifting and transport facilities must be provided to remove the rotating assembly of the centrifuge from its enclosure. Hoist facilities, at a minimum, should be designed for the weight of the rotating assembly. Adequate clearance above and beside the centrifuge should be evident. A monorail with a dual-chain hoist should be installed over the centerline of the machine. Drains, flush water connections and sampling taps should be strategically located in the piping entering and leaving the centrifuge. A blind tee at the entrance to the centrifuge feed pipe can be used for adding polymer, as a cleanout, or for a sample tap.

Progressing-cavity pumps are preferred for sludge feed pumps. The positive displacement and steady-rate characteristics of these pumps permit effective metering and control of the feed rate. Additionally, the hydraulic capacity of progressing-cavity pumps is more nearly a function of pump speed that it is with centrifugal pumps.

Progessing-cavity drives should be variable, permitting at least a five-fold pump range. This allows sufficient flexibility to match variations in solids feed concentration to the solids loading objectives.

A progressing-cavity pump cannot be run dry. Therefore, precautions should be taken to insure wet operation. Flow/pressure detectors for automatic on/off control of the pump should be incorporated into the design. Feed-sludge should be removed from a wet well where the feed is relatively uniform in consistency. Also, these pumps can be used to move solids after they have been thickened in the centrifuges.

In multi-centrifuge installations, a feed distribution system from a single pump may be satisfactory for secondary activated sludge, but this may not be adequate for combined sludges having large, fibrous particles that can cause difficulty in the valves that control distribution. Such sludges are best handled by an individual pump with a variable-speed drive for each centrifuge. During the discharge cycle of each bowl, its feed pump can be stopped or a bypass valve activated to return the feed to the feed tank.

The centrifuge drive motor should be capable of being operated at up to full speed before the feed control can function. The control circuitry should be such that the centrifuge will shut down and the feed to the centrifuge will shut off if there are any malfunctions in the centrifuge.

c. Polymers

Even if polymers are not planned for routine use, a polymer mixing and feeding system should be provided. Chemical conditioning equipment generally is located in the same building as the centrifuge. In larger installations, the equipment may be located on the floor above or below the centrifuge station. Chemicals should be stored near the conditioning equipment. Dry polymer must be kept in a moisture-free environment.

Fresh water under pressure should be used for polymer make-up and secondary dilution. The pressurized water can serve as the source for centrifuge flush water for cleanout at shutdown and for bearing lubrication and cooling water. Wetting of dry polymers requires considerable attention by designers to reduce maintenance and prevent unsafe handling. The wetting device can be difficult to maintain and can cause safety problems when plugging occurs and polymer gets on the floor.

Control of polymer feeding is critical to dewatering control systems and should be as flexible and automatic as possible. A reliable and accurate proportioning system is mandatory for efficient use of polymer. Since polymer solutions can be very viscous, long suction lines or high discharge heads should be avoided. Polymer piping may be of stainless steel or polyvinyl chloride.

Engineers should be aware of potential problems in dealing with dewatering chemicals, including scaling and foaming. Some liquid polymers tend to cause foaming through centrifuges at high dosages. Some polymers may affect the solubility of calcium carbonate and result in scaling of polymer feed lines and process drain lines. The capability to add chemical aids to the polymer should be included in the feed system design if scaling is anticipated.

The point at which chemicals are added will affect performance. Usually, by means of trial and error, it can be determined whether chemicals should be added internally within the centrifuge, or further upstream, perhaps at the suction of the feed pump. The designer of the centrifuge station should consider these points when laying out piping for introducing polymer ahead of the centrifuge.

The cycle time may be controlled by timing, by monitoring the clarity of the centrate, or by sensing the buildup of cake in the bowl. A timer usually is provided for the feed cycle and, as an option, for additional spin time between stopping the feed and starting the discharge.

When a discharge control valve is used, the underflow line should have a horizontal run of no more than 10 feet before discharging vertically into a sump below the centrifuge. This limitation does not apply if a discharge control pump is used. Centrate generally is discharged by gravity back to the headworks of the activated sludge process. An alternative arrangement may include open discharge into a centrate sump with level control for pumping. Closed discharge systems are vented to release entrained air created by the centrifugal action on the liquid leaving the centrifuge.

4. Vacuum Filtration

Waste activated sludge requires very gentle treatment after coagulants are added if optimal filtration is to be achieved. One means of reducing floc destruction is by providing filter tank agitators with on/off timers. The need for agitation is not continuous and varies with sludge concentration. By installing timed variable speed agitators, the operator has the flexibility to adjust the mixing time to maintain homogenous conditions, but yet minimize floc destruction.

A reliable method of controlling the sludge feed rate to a vacuum filter is by using a sludge-level detector in the feed tank. As the level in the tank rises, sludge is fed onto the filter at a more rapid rate. Once the ratio of sludge volume to coagulant volume is determined, the flow of sludge can be used to control coagulant feed. The sludge is metered as it enters the feed tank and this meter, in turn, permits coagulant flow at the predetermined sludge-coagulant ratio.

Consideration should be given to the cleaning, repair and replacement of filter media as it ages and becomes less efficient. Seamless filter cloths are preferred as the earliest holes in seamed cloths appear at the seams. It is recommended that washing showers and troughs be designed to provide up to 10 gallons per minute of wash spray per foot of drum length. This will enable rapid washing of the filter media during or after the occurrence and passage of inadequately conditioned sludge.

Flexible blades for removal of cake from the drums should be provided. The blades will compensate for variations in drum trueness and for deflection in the blade holder across the length of the drum. Blow-back air can be used to billow the cloth as it approaches the sludge scraper. This will help remove stubborn cake but care must be taken to minimize blowback of filtrate water into the cake. Manufacturers must minimize filtrate water blowback into cake during construction.

The form vacuum system, including piping and pump, should be completely separated from the drying vacuum system. This enables the operator to maintain adequate form vacuum regardless of conditions during the drying cycle. This is helpful at startup of filters and at times when filters are not fully coated with sludge and excessive air is flowing through them. If a dual system is not provided, the form cycle will be robbed of sufficient vacuum to pick up sludge.

C. Sludge Stabilization

The purpose of sludge stabilization is to reduce the volume of sludge that must be disposed of and to alter it to a form that is more environmentally acceptable than the unstablilized sludge. There are several techniques available for sludge stabilization. Three of these techniques, anaerobic digestion, aerobic digestion and composting, employ microorganisms to degrade sludge solids. Incineration and heat drying use thermal energy to reduce sludge volume and destroy pathogens.

1. Anaerobic Digestion

Anaerobic digestion takes advantage of the natural process of anaerobiosis to stabilize and reduce the volume of sludge produced in wastewater treatment. Anaerobic bacteria utilizes the organic constituents of sludge, in the absence of oxygen, to respire and reproduce. This process occurs in two steps by two differing groups of bacteria. The first group hydrolyzes and ferments complex organic compounds to simple organic acids. The second group of bacteria converts the organic acids to methane and carbon dioxide. The second reaction step is rate-limiting due to the very slow growth rates of methanogenic bacteria.

Because of the low growth rate and sensitivity of the gas-forming organisms there are a number of factors that affect process performance. A solids retention time of at least 10 days is necessary for the development of gas formers. However, the growth rate of these microorganisms can be accelerated by increasing digester temperature up to about 100 degrees F. The pH of the system is critical for the function of anaerobic digesters. Methanogenic bacteria require a pH range of 6.6 to 7.6 for optimal growth and reproduction. The mixing of digester contents improves performance by insuring uniform contact between organisms and substrate.

a. Process Modifications

Process modifications of anaerobic digestion are made on the basis of mixing and applied loading. Conventional or standard rate digestion is normally a single-stage system with minimal mixing. High-rate systems have two stages, with the first digester being mixed and the second serving as a separator. Where high-rate or two-stage digestion is practiced, provisions should be made to feed and heat the secondary digester. It is recommended that the capability to mix the secondary units be included. The provision to pump secondary digester sludge to the primary units for reseeding and extending sludge detention time is recommended. Digester design should allow for adjustment of pH and alkalinity by chemical addition.

b. Design Considerations

Digester capacity is dependent upon the type of sludge being treated and the degree of stabilization that is required. Activated sludge is more difficult to digest than other sludges, and thus is not conducive to high rate digestion. This implies that when designing for activated sludge digestion, greater digester capacity must be included. If digested sludge is to be completely stabilized, it must be reduced to about 50 percent volatile solids content. This is usually not possible if raw sludge feed contains more than 80 percent volatile solids and average solids retention periods are used. Therefore, the design must allow for larger digester capacity. Completely mixed digesters will always have some short circuiting. With a 10-day detention time, 10 percent of each day's feed theoretically will be short circuited. While secondary digesters have no advantages as far as concentration when used with waste activated sludge, they can be a useful tool to prevent short circuiting.

Both fixed and floating covers have been used in anaerobic digester design. Floating covers are advantageous, for they allow the operator to add feed sludge without concurrently withdrawing digested sludge. Additionally, fixed covers can develop gas leaks more easily than the floating type. In designing floating covers, sufficient ballast should be added to the cover skirts to minimize the gas/liquid interface (see Figure 12.4). Waste activated sludge tends to produce foam in digesters. This can lead to an unstable floating cover. The use of skirt ballast will alleviate this problem.

Floating cover design should include at least a 12- to 18-inch freeboard and a 12- to 24-inch skirt. The side clearance between the cover and the tank body should be no more than 3 inches. This requires strict tolerances in tank and cover construction. Since floating covers can move up and down several feet, flexible hose should be used for lines entering the digester through the cover.

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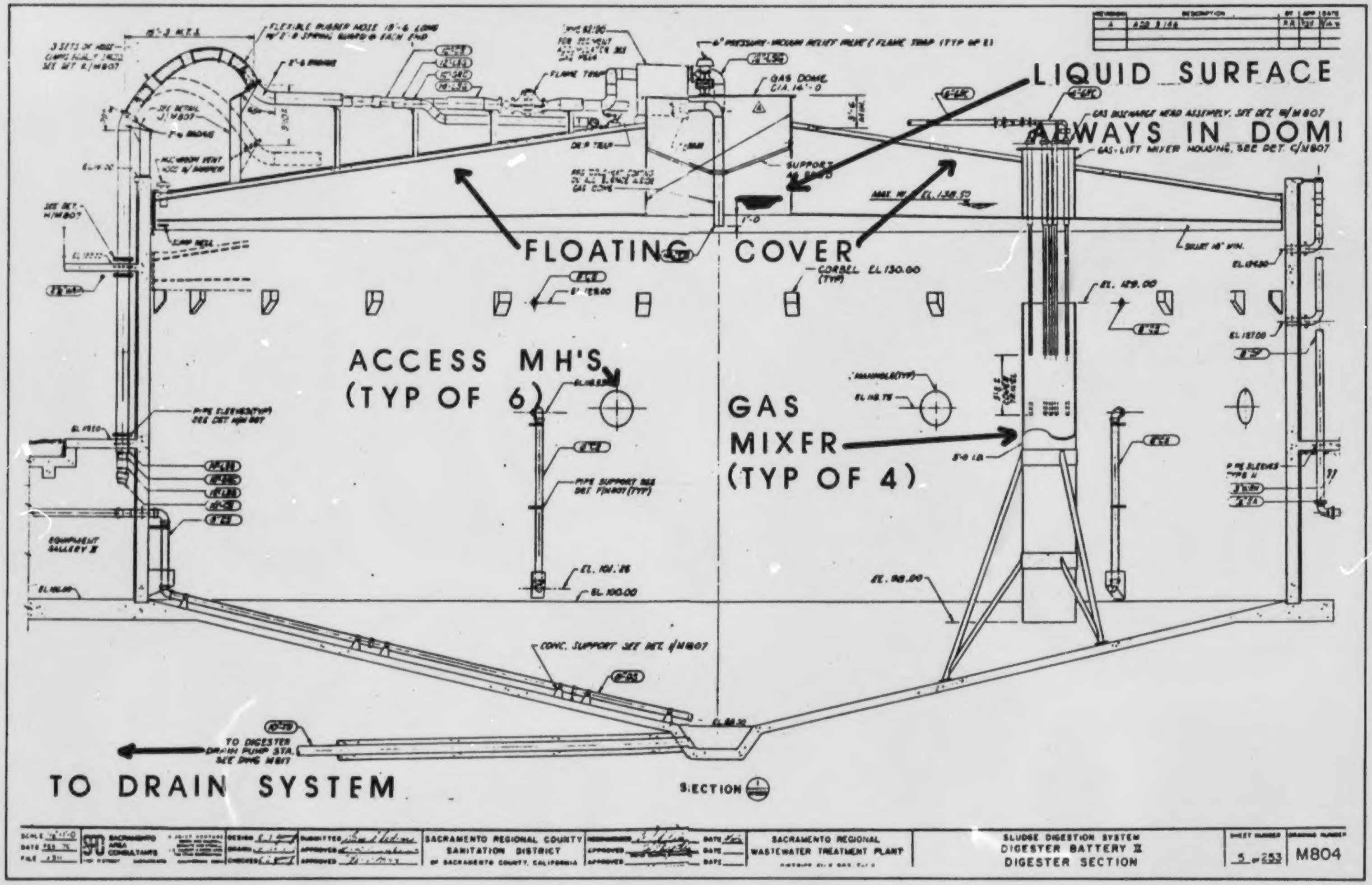

LIQUID SURFACE
ALWAYS IN DOME
GAS DOME DIA. 14'-0
SUPPORT
MAX. W.S. EL. 138.50
FLOATING COVER
CORBEL EL 130.00 (TYP)
EL. 129.00
ACCESS MH'S (TYP OF 6)
GAS
MIXER
(TYP OF 4)
PIPE SUPPORT SEE DET. F/M807 (TYP)
EQUIPMENT GALLERY II
EL. 101.26
EL. 100.00
EL. 98.00
CONC. SUPPORT SEE DET. H/M807
TO DIGESTER DRAIN PUMP STA. SEE DWG M811
TO DRAIN SYSTEM
SECTION
SACRAMENTO AREA CONSULTANTS
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
SLUDGE DIGESTION SYSTEM
DIGESTER BATTERY II
DIGESTER SECTION
5 of 253
M804

FIGURE 12.4 FLOATING COVER ON SLUDGE DIGESTER

Mixing digester contents is best accomplished using digester gas circulation. The application of mechanical mixing may be difficult if a floating cover is used. Bearings and blades may pose maintenance difficulties with this type of mixing. If sludge circulation is used for digester mixing, a great deal of energy may be required to blend the entire digester contents. However, this form of mixing can be effective if used in conjunction with gas circulation. When digester gas is used for mixing, there should be complete independence of this mechanism and the system used to remove gas for other uses (see Figures 12.5 and 12.6). With the exception of draft tube gas mixers, all piping should be placed against the walls of a digester to avoid hanging up debris.

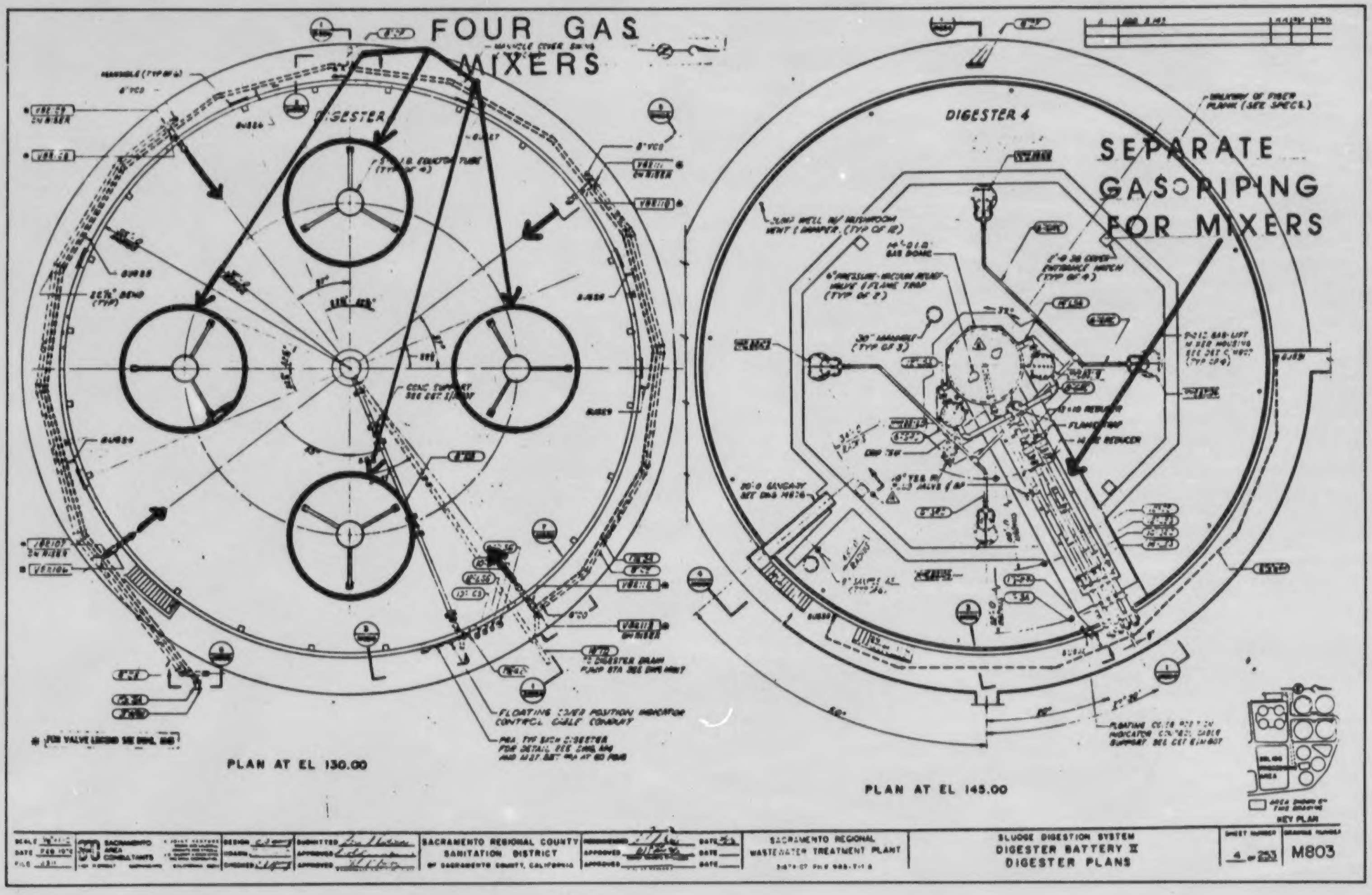
Sludge within a digester must be heated to keep methanogenic bacteria growing and reproducing at an acceptable rate. Internal heat exchangers have been all but abandoned for this purpose due to maintenance difficulties. However, if used in conjunction with draft tube mixers, it is possible to design removable internal exchangers. Direct steam injection is noisy and subject to control failures which may result in excessive heating of piping and digester covers. External heat exchangers are the most useful means of maintaining digester temperatures. The spiral and concentric tube types are the most energy efficient units (see Figure 12.7). However, no matter which method of heating is chosen, insulation on all piping and tanks should be included to reduce the amount of digester gas required for heating.

Digesters using reclaimed heat should have standby heating capabilities for periods when the heating engines are down. A standby supply of liquid propane for the engines should be available during periods of digester gas production failure. Hot water piping in multiple engine installations should be segregated for quick detection of engine-oil leakage into the water. Therefore, individual boilers for each digester are preferred over a single large boiler tied to the manifold line.

Anaerobic digesters should be fed as often as it is practical based upon design constraints. Raw sludge should never be fed to a digester without first mixing it with circulating sludge from the digester. Mixing is often best accomplished at the point of raw sludge withdrawal. This insures that raw and digester sludges will be blended when they reach the digester. Digester design should include flexibility in input and drawoff of sludge. This can be done using quarter point circulation (i.e., have access to the digester at four points along its circumference) (see Figure 12.8). Additionally, there should be the capability for bottom center or top center input and withdrawal.

Positive displacement pumps should be used for sludge withdrawal. These assure maximum control of sludge removal. Positive displacement pumps are unaffected by the solids content of the sludge.

Gas production is a measure of the digester function. Therefore, it is important that gas production be monitored. Simple orifice meters appear to hold up best. However, their range of measurement is limited, so they will not measure extremely low gas production. Digester gas


FOUR GAS MIXERS
DIGESTER 3
DIGESTER 4
SEPARATE GAS PIPING FOR MIXERS
PLAN AT EL 130.00
PLAN AT EL 145.00
FLOATING COVER POSITION INDICATOR CONTROL CABLE CONDUIT
KEY PLAN
SACRAMENTO AREA CONSULTANTS
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT
OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
SLUDGE DIGESTION SYSTEM
DIGESTER BATTERY II
DIGESTER PLANS
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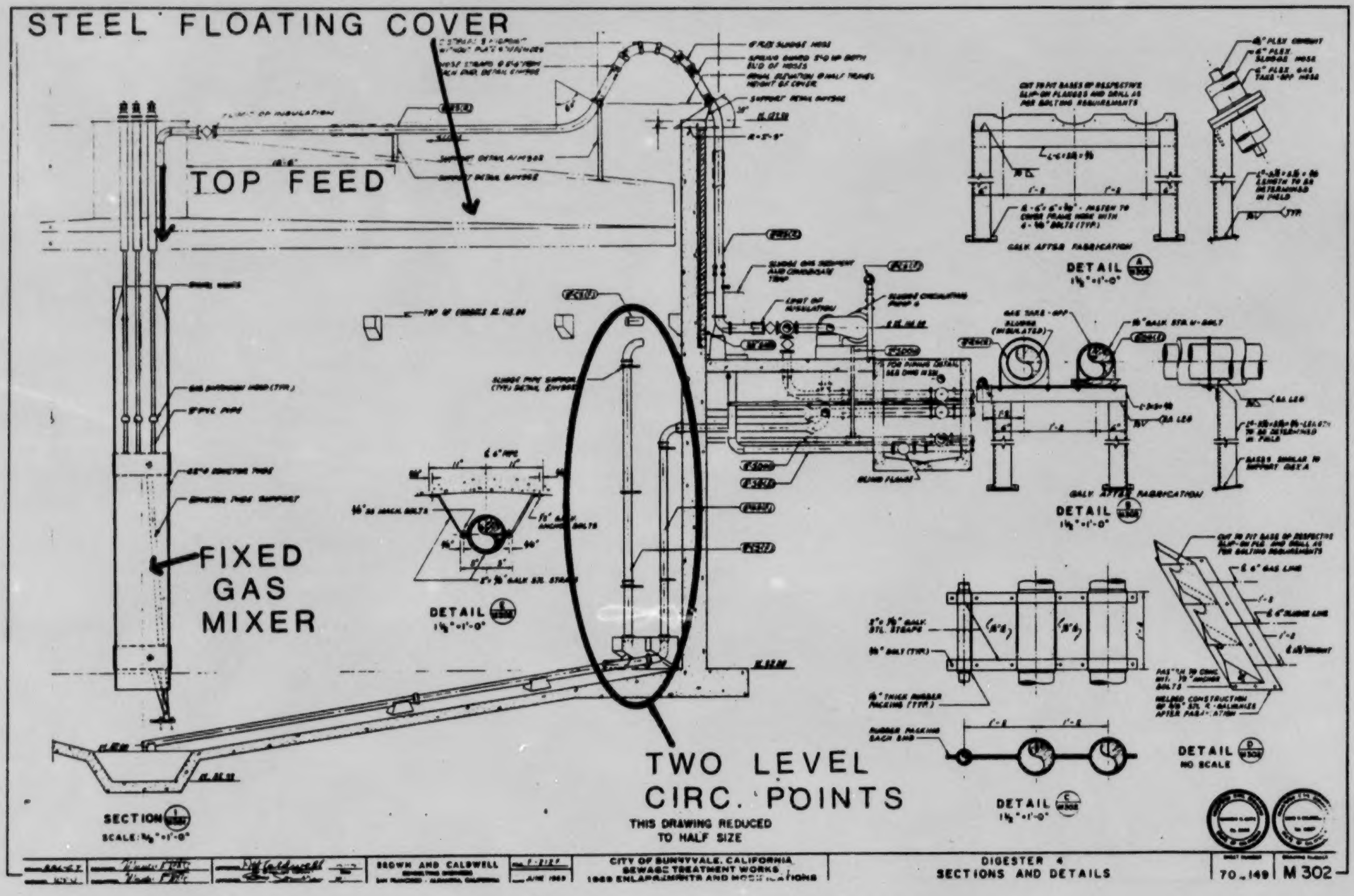
M803

FIGURE 12.5 DIGESTER GAS USED FOR MIXING


STEEL FLOATING COVER
TOP FEED
FIXED GAS MIXER
TWO LEVEL CIRC. POINTS
SECTION
DETAIL A
DETAIL B
DETAIL C
DETAIL D
NO SCALE
GALV AFTER FABRICATION
THIS DRAWING REDUCED TO HALF SIZE
BROWN AND CALDWELL
CITY OF SUNNYVALE, CALIFORNIA
SEWAGE TREATMENT WORKS
1969 ENLARGEMENTS AND MODIFICATIONS
DIGESTER 4
SECTIONS AND DETAILS
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M 302

FIGURE 12.6 TWO LEVEL GAS CIRCULATION SYSTEM

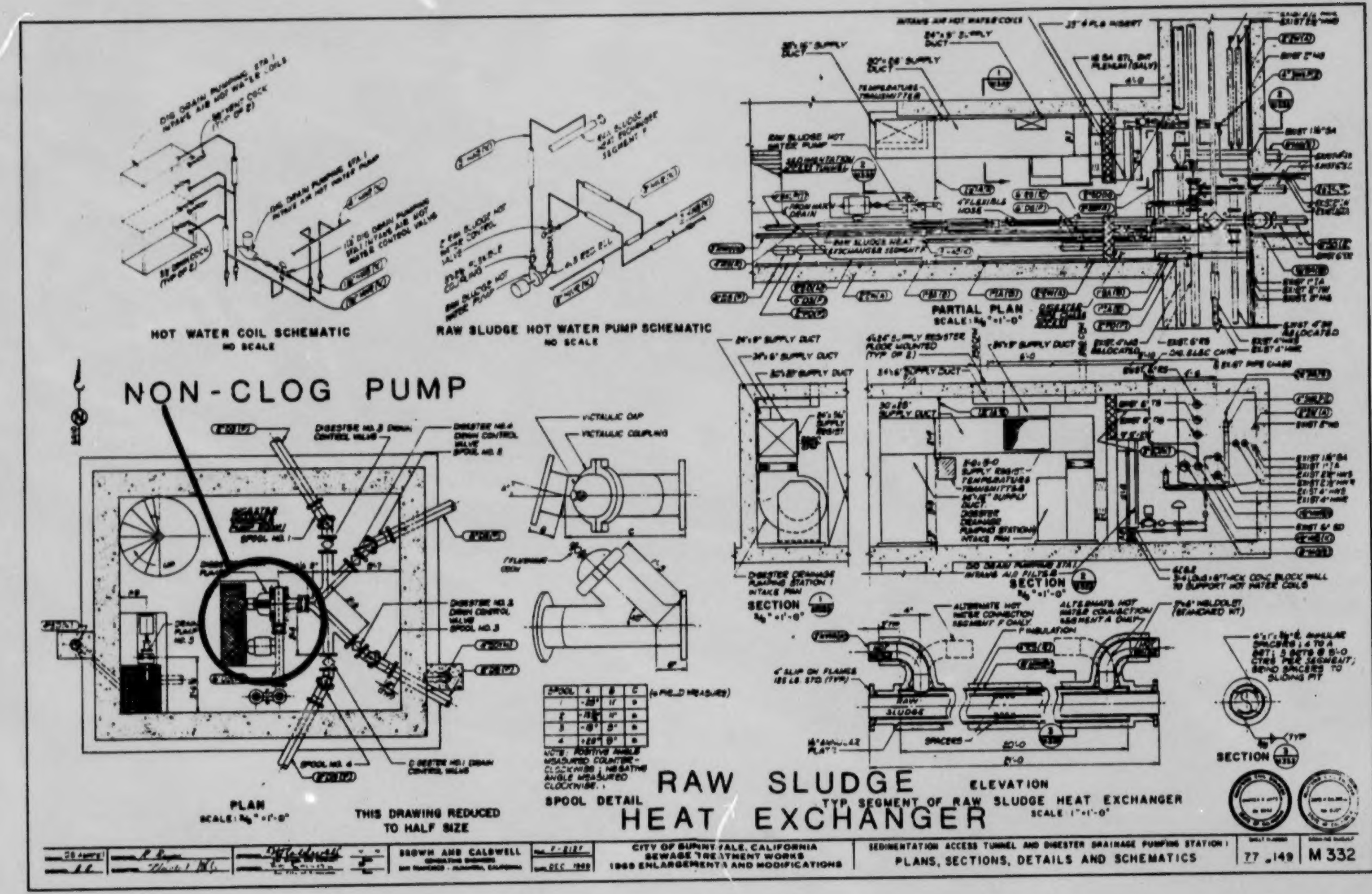

HOT WATER COIL SCHEMATIC
NO SCALE
RAW SLUDGE HOT WATER PUMP SCHEMATIC
NO SCALE
PARTIAL PLAN
NON-CLOG PUMP
SPOOL DETAIL
SECTION
ELEVATION
TYP. SEGMENT OF RAW SLUDGE HEAT EXCHANGER
SCALE: 1"=1'-0"
PLAN
THIS DRAWING REDUCED TO HALF SIZE
RAW SLUDGE HEAT EXCHANGER
BROWN AND CALDWELL
CITY OF SUNNYVALE, CALIFORNIA
SEWAGE TREATMENT WORKS
1969 ENLARGEMENTS AND MODIFICATIONS
SEDIMENTATION ACCESS TUNNEL AND DIGESTER DRAINAGE PUMPING STATION I
PLANS, SECTIONS, DETAILS AND SCHEMATICS
77 149
M 332

FIGURE 12.7 RAW SLUDGE HEAT EXCHANGER

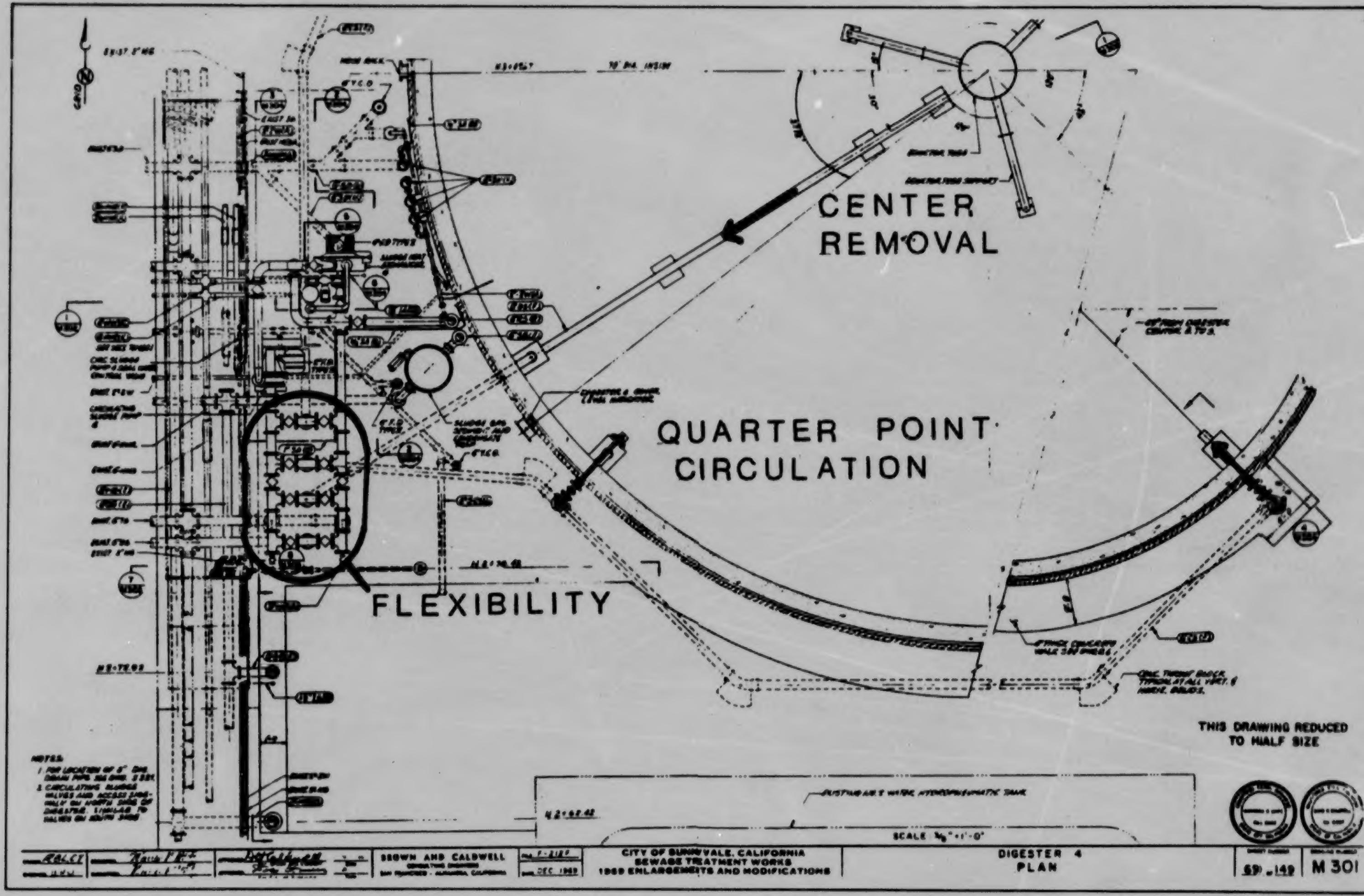

CENTER
REMOVAL
QUARTER POINT
CIRCULATION
FLEXIBILITY
THIS DRAWING REDUCED
TO HALF SIZE
BROWN AND CALDWELL
CITY OF SUNNYVALE, CALIFORNIA
SEWAGE TREATMENT WORKS
1969 ENLARGEMENTS AND MODIFICATIONS
DIGESTER 4
PLAN
69-149
M 301

FIGURE 12.8 QUARTER POINT CIRCULATION FOR FLEXIBILITY

is 100 percent saturated with moisture as it leaves the digester. Cold exposed piping will immediately condense excess moisture, thus, sediment and moisture traps must be provided in conjunction with this piping.

Methane produced in anaerobic digesters is most efficiently used for in-plant power and treatment needs. The most efficient in-plant use is running direct drive engines followed by use in boilers and on-site generation of electricity. The gas can be used without scrubbing if boiler and engine temperatures are kept at or above 200 degrees F.

Digesters must be drained and cleaned periodically to remove accumulations of grit and debris. For this reason, access to the interior of the digester should be provided. This should include both cover access and several pressure manholes around the side of the tank. Digesters should be provided with a large debris handling pump station to remove grit and debris. The station should be located below the lowest point of each digester so that the pump can operate with a positive suction head at all times. Drain pipes should be at least eight inches in diameter (see Figures 12.9 and 12.10).

2. Aerobic Digestion

Aerobic digestion is similar to the activated sludge process. As the supply of substrate is diminished, the microorganisms will begin to consume their own protoplasm to obtain energy for cell maintenance reactions. When this occurs, the cells are in the endogenous growth phase. About 75 to 80 percent of the cellular components can be oxidized aerobically. The remainder is composed of biologically inert compounds and undegradable organic materials.

Advantages claimed for aerobic digestion as compared to anaerobic digestion include: (1) volatile-solids reduction approximately equal to anaerobic digestion; (2) lower BOD concentrations in the supernatant liquor; (3) production of an odorless, biologically stable end product; (4) production of a sludge with excellent dewatering properties; (5) recovery of the fertilizer values of the sludge; (6) fewer operational problems; and (7) lower capital cost. However, aerobic digestion is energy intensive and does not produce a useful by-product such as methane. To date, aerobic digestion has been used primarily in small extended aeration and contact stabilization plants.

Normally, a minimum of 15 days retention is required for waste activated sludge and 20 days for primary sludge or combined WAS/primary sludge. Where sludge temperature is below 50 degrees F, additional retention time should be considered. Provisions for covering tanks to prevent heat loss should be considered.

The use of multiple tanks is recommended. However, a single tank may be adequate for a small treatment plant or where adequate provision is made for sludge handling. When multiple units are provided, the ability to use them in series is recommended.

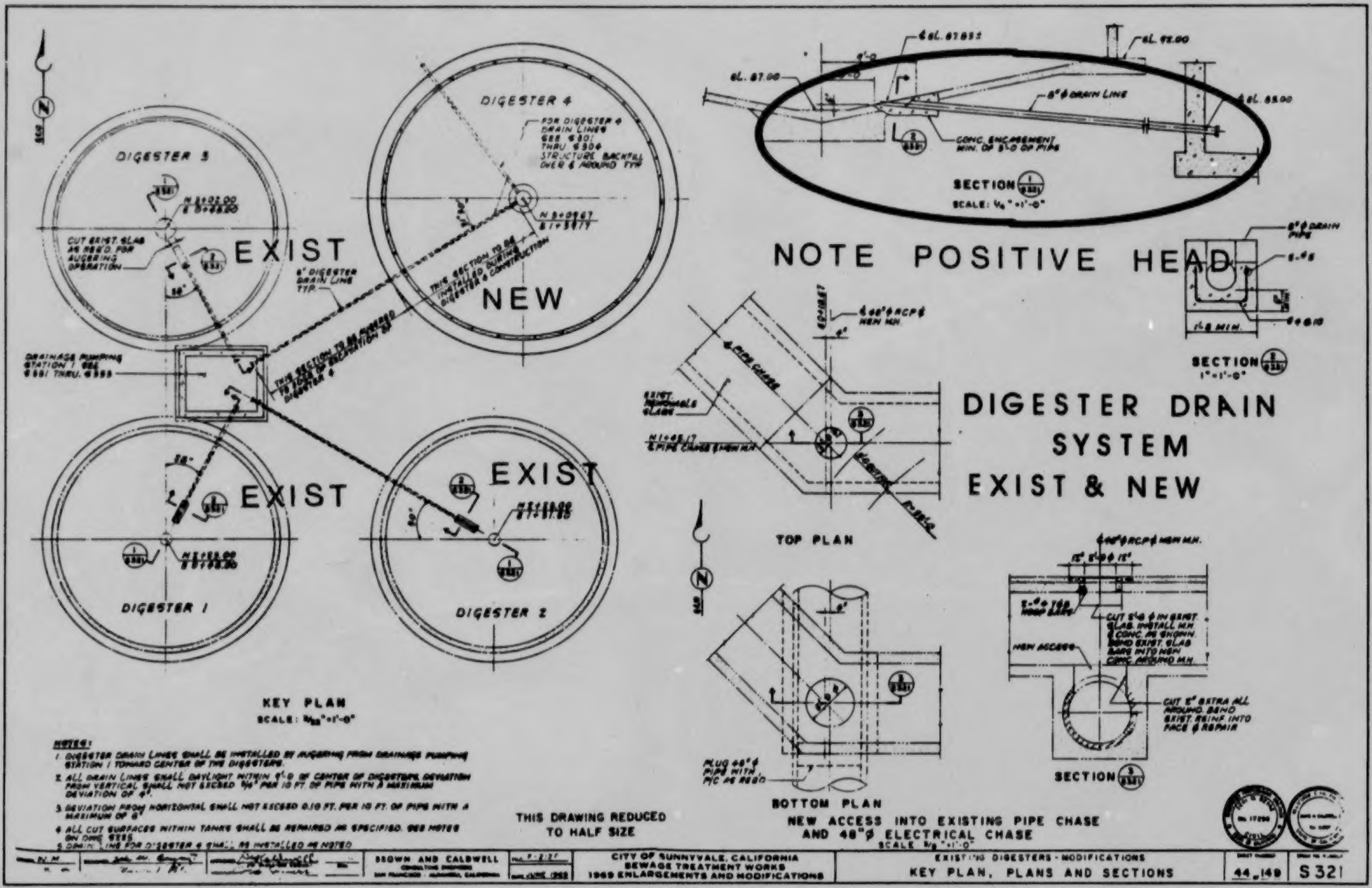
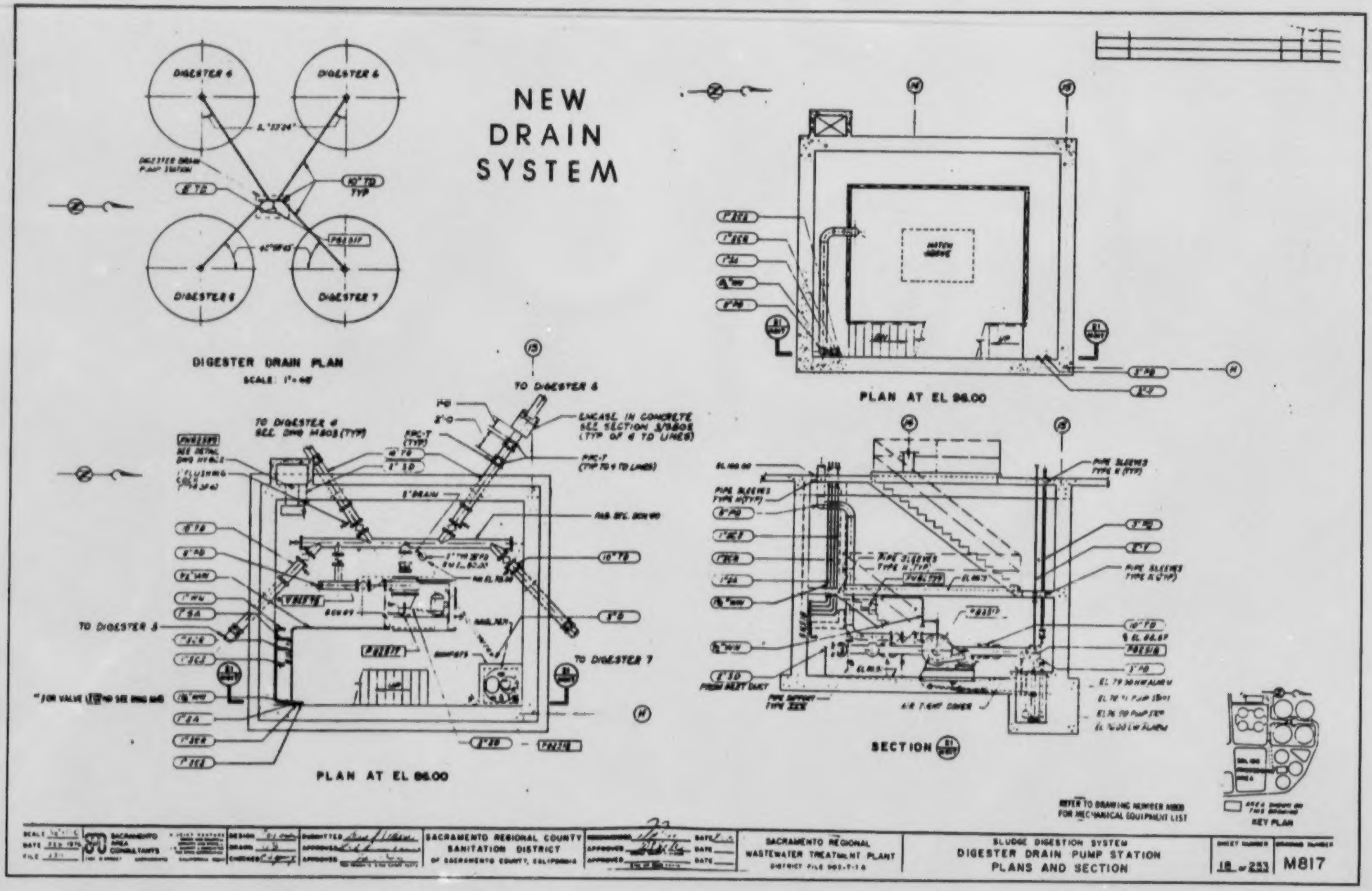

DIGESTER 3
DIGESTER 4
DIGESTER 1
DIGESTER 2
EXIST
NEW
EXIST
EXIST
FOR DIGESTER 4 DRAIN LINES SEE S301 THRU S304 STRUCTURE BACKFILL OVER & AROUND TYP
CUT EXIST. SLAB AS REQ'D FOR AUGERING OPERATION
6" DIGESTER DRAIN LINE TYP.
DRAINAGE PUMPING STATION 1 SEE S351 THRU. S353
THIS SECTION TO BE INSTALLED DURING DIGESTER 4 CONSTRUCTION
KEY PLAN
SCALE: 3/32"=1'-0"
NOTES:
1 DIGESTER DRAIN LINES SHALL BE INSTALLED BY AUGERING FROM DRAINAGE PUMPING STATION 1 TOWARD CENTER OF THE DIGESTERS.
2 ALL DRAIN LINES SHALL DAYLIGHT WITHIN 1'-0 OF CENTER OF DIGESTERS. DEVIATION FROM VERTICAL SHALL NOT EXCEED 1/2" PER 10 FT. OF PIPE WITH A MAXIMUM DEVIATION OF 4".
3 DEVIATION FROM HORIZONTAL SHALL NOT EXCEED 0.10 FT. PER 10 FT. OF PIPE WITH A MAXIMUM OF 6"
4 ALL CUT SURFACES WITHIN TANKS SHALL BE REPAIRED AS SPECIFIED. SEE NOTES ON DWG S325
5 DRAIN LINE FOR DIGESTER 4 SHALL BE INSTALLED AS NOTED
THIS DRAWING REDUCED TO HALF SIZE
EL. 87.00
EL. 87.833
EL. 92.00
EL. 85.00
6" Ø DRAIN LINE
CONC. ENCASEMENT MIN. OF 3"-0 OF PIPE
SECTION 1
SCALE: 1/4"=1'-0"
NOTE POSITIVE HEAD
SECTION 2
1"=1'-0"
DIGESTER DRAIN SYSTEM EXIST & NEW
TOP PLAN
BOTTOM PLAN
PLUG 48" Ø PIPE WITH P/C AS REQ'D
NEW ACCESS INTO EXISTING PIPE CHASE AND 48"Ø ELECTRICAL CHASE
SCALE 3/8"=1'-0"
NEW ACCESS
CUT 5" EXTRA ALL AROUND. BEND EXIST. REINF INTO FACE & REPAIR
SECTION 3
BROWN AND CALDWELL
CITY OF SUNNYVALE, CALIFORNIA
SEWAGE TREATMENT WORKS
1969 ENLARGEMENTS AND MODIFICATIONS
EXISTING DIGESTERS - MODIFICATIONS
KEY PLAN, PLANS AND SECTIONS
44_149
S321

FIGURE 12.9 DIGESTER DRAIN SYSTEM


NEW
DRAIN
SYSTEM
DIGESTER 4
DIGESTER 5
DIGESTER 6
DIGESTER 7
DIGESTER DRAIN PLAN
PLAN AT EL 86.00
TO DIGESTER 5
TO DIGESTER 4
TO DIGESTER 6
TO DIGESTER 7
SECTION
REFER TO DRAWING NUMBER M800 FOR MECHANICAL EQUIPMENT LIST
KEY PLAN
SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT OF SACRAMENTO COUNTY, CALIFORNIA
SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT
SLUDGE DIGESTION SYSTEM
DIGESTER DRAIN PUMP STATION
PLANS AND SECTION
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M817

FIGURE 12.10 DIGESTER DRAIN SYSTEM

Enough mixing capability should be provided to permit at least 30 cfm of air per 1000 cubic feet of tank volume with the largest blower out of service. If diffusers are used, the non-clog type is recommended. If mechanical aerators are used, submerged turbine units or floating surface aerators are desirable to permit liquid level variation. The use of mechanical equipment is discouraged where freezing temperatures are normally expected. Other features which can affect the operability of an aerobic digester include adequate storage capacity for retaining sludge during winter, efficient piping arrangement for decanting supernatant, and good accessibility to the air diffusers for cleaning and maintenance of the equipment.

3. Incineration and Heat Drying

Since both of these processes are energy intensive, consideration should be given to recovering heat for plant uses wherever practical. Incineration considerations should include providing sufficient storage of combustible materials, the provision of effective equipment for blending sludge cake with dry or organic material, an effective means for controlling the solids concentration, and a suitable means for ash removal and disposal. Heat drying may have more mechanical components than an incinerator and, therefore, accessibility to equipment for maintenance and emergency repairs is essential. Equipment for recycling dried sludge with cake should be included for temperature and moisture control. Exhaust gases can be laden with particles, aerosols and detrimental gas products. Thus, after-burners may be necessary to obtain satisfactory emissions to the atmosphere.

4. Composting

Composting facilities should have well-drained working surfaces. A reliable means for separating the bulking agent from composted sludge is required. Ample room for maneuvering equipment, storage of raw and composted sludges, and control facilities should be included.

D. Sludge Conveyance Considerations

1. Sludge Properties of Concern

With few exceptions, dilute wastewater sludges have fluid properties similar to water (i.e., an incompressible and homogenous Newtonian fluid). As sludge solids concentration and/or volatile solids concentration increases, sludge fluid characteristics will deviate from that of water and will behave as a non-Newtonian liquid. Thickened sludges, some primary sludges and digested sludges fall into this category. Other deviations from typical liquid behavior result from the debris contained in raw and wasted sludges, as well as from entrained gases, especially in decomposing and septic sludge streams. The fluid properties of cold sludges during winter may vary significantly from those of pure water at standard temperature and pressure. If conditions permit, the designer should assess in advance the fluid properties of the sludge to be handled by performing viscosity studies and/or controlled flow rate studies.

2. Pumps

The designer should provide sufficient head capabilities in pumps to accommodate the increased system head due to sludge viscosities which may be higher than water. The designer should provide the proper horsepower of pump motors so overloading is avoided in the event that a sludge thins out and becomes less viscous in character. A means for controlling occasional higher flow rates should be included. Easy clean out should be present on all pumps.

3. Pipes

Piping should be large enough to avoid clogging by rags and matted debris, and should be large enough to avoid excess friction loss on the suction side of sludge pumps. The piping system should have sufficient valves to provide flexibility for routing flows and for isolating equipment when maintenance is needed. Situations should be avoided where raw sludges can be trapped between two closed valves. If such a situation is unavoidable, operations personnel should be alerted to the potential of decomposition and excessive pressures in the closed section of piping. One-quarter-turn plug and ball valves are easy for operators to utilize and permit a certain degree of throttling control. Check valves should have, for the operator's benefit, an external arm to indicate check valve position and, therefore, the presence or absence of flow.

4. Conveyors

At transfers from sludge dewatering equipment to belt conveyors, or from conveyor to conveyor, splashing of dewatered sludge can occur. Thus, total enclosure of the dump point and minimal drop distances are recommended. The installation of rubber gaskets from hoppers to conveyor skirts and the addition of covered skirtboards can reduce splashing. It may be best to minimize the drop distance even at the expense of maintenance headroom. In the long run, less maintenance will be required.

Scraping sludge off return belts is difficult. Counter-weighed rubber-bladed scrapers at head pulleys are not effective and are maintenance problems. The use of "finger"-type scrapers is recommended. The use of shock absorbers can reduce blade bounce and keep them in contact with the conveyor belt. Scrapers should be installed off the roller on a flattened portion of the belt to insure continuous contact between scraper and belt.

Snubber pulleys, belt trippers, gravity take-ups or other devices require the side of the belt conveying sludge to turn over a pulley. This can result in pulleys slipping or scraping sludge off the belt and should be avoided in design. The use of screw, cylinder or counter-weighted take-up is recommended. In the case of long lifts, two short belts should be used instead of one long belt to avoid the need for gravity pickups. Catch basins, sumps or drainage are necessary at all dump points.

The most important feature for maintaining a sludge conveying system is flexibility. Most sludge conveyors should be able to either receive or discharge sludge to two or more locations. Shuttle conveyors (conveyor on rails), rubber-bladed belt plows, reversible conveyors and duplicate belt conveyors can all aid in the prevention of conveyance problems.

Maintenance requirements of the conveyance system should be considered in design. Ample space is required around the conveyors to permit preventive and emergency maintenance. Most belts should be reversible and should have a means for increasing tension on the belt as the belt elongates with time. Effective cleaning facilities, such as scrapers and water sprays, should be included if conveyed sludges do not fall free from the conveyors. Easy replacement of the belt is a must.

PROCESS DESIGN - OTHER BIOLOGICAL PROCESSES

UNIT 13

UNIT 13 - PROCESS DESIGN - OTHER BIOLOGICAL PROCESSES

OBJECTIVES

At the conclusion of this presentation, the attendee should be able to:

- Define aerobic treatment.
- Describe well-designed trickling filters.
- List three advantages of trickling filters over activated sludge.
- List at least five "design hints" for trickling filters.
- Design underdrains for trickling filters.
- Identify ventilation needs for trickling filters.
- State at least four "design hints" for sludge production and handling in trickling filters.
- List four "design hints" for "cold weather" trickling filters.
- Describe operation of rotating biological contactors (RBC).
- List two RBC process alternatives.
- List at least four disadvantages of RBC's.
- Design RBC's for flexibility of operation.
- Discuss the design options available for stabilizaton ponds.
- List at least four "design hints" for stabilization ponds.

UNIT 13 - PROCESS DESIGN - OTHER BIOLOGICAL PROCESSES

I. INTRODUCTION

Secondary treatment implies the use of microorganisms to reduce the soluble organic concentration of wastewater. Aerobic processes are most often used to treat municipal wastewater, as these methods of treatment are less offensive and more easily controlled than anaerobiosis. In recent years, the activated sludge process and its modifications have seen extensive application in new wastewater treatment facilities of all sizes. However, the other aerobic processes, namely, trickling filters, rotating biological contactors (RBC) and wastewater stabilization ponds, are still used in smaller municipalities.

Even though these processes are all aerobic, they differ considerably in the fashion in which they effect treatment. Activated sludge relies on the growth of a concentrated suspension of microorganisms to reduce soluble organic loadings. Trickling filters and RBC's contact wastewater with a fixed film of microorganisms to accomplish this same objective. In stabilization ponds, the biological community is similar to that in the activated sludge system. However, instead of mechanical aeration, algae provide the oxygen necessary for bacterial metabolism. Because of these differences in the mode of treatment, designs vary considerably among the aerobic processes. Design considerations for activated sludge have already been discussed in Unit 8; the focus of this unit will be on considerations for operability and maintainability of trickling filters, RBC's and stabilization ponds.

II. TRICKLING FILTERS

A. General Considerations

The trickling filter is a fixed film process in which wastewater is allowed to percolate through a bed consisting of stones, slats or plastic media. A bacterial slime grows on the media and consumes soluble BOD from the wastewater. The slime will continue to grow and become thicker until it is sloughed off the media and flushed out of the filter with the percolate. The excess growth is removed in a sedimentation basin and the clarified effluent is discharged.

Trickling filters have advantages over activated sludge that can make this process attractive, especially for smaller communities. Trickling filters are easier to operate and require fewer process adjustments than activated sludge reactors. Trickling filters generally have lower energy requirements than activated sludge. Energy utilized by filters is a function of the amount of recycle required and the available treatment plant head.

Finally, by employing deep filters and high recycle rates, the space required for secondary treatment can be kept relatively small.

However, the fixed film process does have disadvantages that are not found in activated sludge. In trickling filters there is a large fixed surface area of microbial growth exposed to ambient air. This makes the process very temperature sensitive, thus, treatment quality can change during the course of the year. Because wastewater percolates through a media bed in a trickling filter, the effective contact time between microorganisms and wastewater is less than in activated sludge. Finally, there is a considerable head difference between the influent and effluent ends of a trickling filter. Depending on the plant layout, this can necessitate large energy requirements to provide the required head.

Trickling filters can be grouped into three generic categories as follows: (1) low rate, (2) high rate and (3) roughing rate. Low rate filters can remove 5 to 25 lb BOD/1000 ft^3 of filter/day; high rate, 25 to 100 lb BOD/1000 ft^3/day; and roughing rate more than 100 lb BOD/1000 ft^3/day. Similarly, hydraulic loadings vary among these filters as follows: low rate, 25 to 100 gpd/ft^2 of media; high rate, 100 to 1000 gpd/ft^2; and roughing rate, 700 to 3000 gpd/ft^2. Table 13.1 contains pertinent information on the three trickling filter categories.

Because of the unstable characteristics of the biological slime layer and unpredictable hydraulic characteristics, a kinetic model of the trickling filter is very difficult to develop. For this reason, the design of trickling filters has been based on empirical relationships. A number of design equations have been proposed. Table 13.2 summarizes some of the major formulas.

Terms in the table are:

E_1 = Percent BOD removal efficiency through first-stage filter and clarifier
E_2 = Percent BOD removal efficiency through second-stage filter and clarifier
W = BOD loading to first-stage filter
W_1 = BOD loading to second-stage filter
L_D = Removable BOD at depth D
L = Total removable BOD
K_1 = Constant
L_e = Unsettled filter effluent BOD
L_i = Filter influent BOD
i = Influent flow
r = Recirculation flow
a = Filter radius
T = Wastewater temperature
Q_1 = Hydraulic load
K_3 = Treatability constant
Q = Flow
L_o = Influent BOD
A = Area of filter

Table 13.1

TRICKLING FILTER PROCESS FILTER CLASSIFICATIONS AND CHARACTERISTICS

PARAMETER	UNITS	LOW-RATE	HIGH-RATE	ROUGHING RATE
Type of Media		Crushed rock, cinders, slag, of field stone.	Crushed rock, cinders, slag, field stone, redwood lath or blocks, or molded plastic.	Any of the previously given materials.
Media Depth	ft (m)	5 to 10 (1.5 to 3.0)	3 to 8 (0.9 to 2.4)	10 to 30*** (3.0 to 9.1)
Organic* Loading	lb BOD/day/ 1000 cu ft (kg BOD/m^3d)	5 to 25 (0.8 to 0.4)	25 to 100 (0.4 to 1.6)	100 plus (1.6 plus)
Hydraulic Loading	gpd/sq ft (m^3/m^2d)	25 to 100 (1.0 to 4.1)	100 to 1000 (4.1 to 40.7)	700 to 3000*** (28.6 to 122.2)
Recirculation Ratio	R/Q **	Sometimes included	0.5 to 2.0	0.5 to 4.0
Sloughings		Intermittent Brown in color, well-stabilized	Continuous Brown in color, unstable	Continuous Brown in color, highly unstable
Clarifier Surface Overflow Rate	gpd/sq ft (m^3m^2d)	1000 (40.7)	800 (32.6)	1000 (40.7) (may not be included)

* The organic loadings given are typical for regions having mild winters. Lower loadings are required in regions having low winter temperatures.

** Recirculation ratio = Recirculation flow divided by raw wastewater flow.

*** Applicable to synthetic media-filled roughing filters. Refer to "High-Rate" column for data pertaining to rock-filled roughing filters.

Reprinted from Process Control Manual for Aerobic Biological Wastewater Treatment Facilities, EPA, March, 1977.

TABLE 13.2
TRICKLING FILTER DESIGN FORMULAS

Formula	Remarks	References
First Stage: $E_1 = \frac{100}{1 + 0.0085 \left(\frac{W}{V \cdot F}\right)^{1/2}}$ Second Stage: $\frac{100}{1 + \frac{0.0085}{1 - E_1} \left(\frac{W_1}{V \cdot F}\right)^{1/2}}$	Applicable to stone media filter	NRC, 1946
$\frac{L_p}{L} = 10^{-K_1 D}$	Applicable to stone or synthetic media	Velz, 1960
$Le = \frac{K_2 (iL_i + rL_e)^{1.19}}{(i + r)^{0.78} (1 + D)^{0.67} a^{0.25}}$ where $K_2 = \frac{0.464 \frac{43560}{\pi}}{i^{0.28} T^{0.15}}$	Applicable to stone media	Galler and Gotaas, 1966
$\frac{L_e}{L_i} = e - \frac{K_3 D}{Q_i^n}$	Applicable to stone and synthetic media	Schulze, 1960
$\frac{L_e}{L_i} = e - \frac{1.042^{(T-20)} \times K_{20} D}{Q_i^n}$	Applicable to Dowpac media; corrected for temperature	Germaine, 1966
$\frac{L_e}{L_o} = \frac{1}{1 + \frac{CD^{(1-m)}}{\left(\frac{Q}{A}\right)^n}}$, $L_o = \frac{L_i + rL_e}{1 + r}$	Applicable to stone and synthetic media	Eckenfelder, 1963

M, n - Constants for particular media
k_{20} - Treatability constant at 20 degrees C
V - Volume of filter
F - Recirculation factor

Almost all the design formulas are based on first-order biological kinetics. Application of appropriate models shows that for a given set of conditions two filters, operating in series, will give improved performance over two filters operating in parallel. It is, thus, suggested that all designs utilize at least two filters operating in series. When filters are operated in this fashion, it is advantageous to be able to alternate the lead filter in each pair in order to maintain slime thickness at optimal levels and thus reduce clogging potential.

Various combinations of recycle and clarifier units have been utilized with success. Some of the common configurations can be found in the WPCF, Manual of Practice, No. 8, "Sewage Treatment Plant Design," 1967.

Trickling filter media may consist of any uniformly sized material that is durable and insoluble. Granite media, 3 to 5 inches in diameter, has traditionally been used in beds 3 to 8 feet deep. However, several forms of manufactured media have been introduced in recent years, including redwood slats, corrugated plastic modules and plastic saddles. The advantages of these designs are: (1) greater surface area per unit volume, (2) greater void space per unit volume, (3) more uniform liquid distribution, (4) lighter weight modules which allow construction of deeper beds, and (5) increased chemical resistance.

The wastewater distribution system for most trickling filters consists of a rotary distributor driven by the force of the wastewater itself. The arms should be sized to prevent velocities greater than 4 rpm and only 2 arms should carry influent during low flow periods. Several design features for distribution arms that alleviate maintenance problems in trickling filters include: adjustable tie rods on the arms, a dump gate on the end of each arm for flushing obstructions, some means of spraying the interior wall of the filter to prevent buildup of filter flies, and a drain plug in the center of the distributor to facilitate shutdown and prevent freezing.

The hydraulic head required for dosing can be provided by pumps, gravity discharge or dosing tanks. The latter can be equipped with automatic siphons for controlling maximum and minimum head conditions. Any dosing equipment should be provided with flow meters. These meters will provide information on the amount of influent and recycle and, in the case of multiple filters, permit equal distribution of flow among all units.

If distributor arms are rotated hydraulically, then it is important that the design include provisions to keep them rotating under low flow conditions. This can be accomplished by increasing the recirculation rate as plant inflow decreases.

Recirculation of treated wastewater is a common practice in trickling filter design and operation. Using recirculation, low rate filters can be converted to high rate systems. Recirculation is used with synthetic media to maintain at least a 0.6 gpm/ft^2 wetting rate. Recirculation is essential on roughing rate systems to increase contact time and improve mass transfer. There are other advantages and disadvantages associated with recirculation which should be considered by the Design Engineer. Some of these are summarized in Table 13.3.

TABLE 13.3

ADVANTAGES AND DISADVANTAGES OF RECIRCULATION ON TRICKLING FILTERS

Advantages	Disadvantages
Prevents slime from drying out during low flow	Reduces wastewater temperature, lowering the rate of biological activity
Washes filter fly eggs and larvae through filter	Increases hydraulic loading on sedimentation basins
Dilutes high strength wastes and improves oxygen transfer	Increases operational costs due to pumping
Flushes excessive growth in media, preventing ponding and channelization	
Maintains biological growth through synthetic media	
Improves wastewater distribution over the filter surface	

In trickling filter plant design, many modes of recirculation are possible. Often the simplest method in smaller plants is to design for a constant recirculation. This will run continuously, except perhaps at very high flows when the recirculation pump can be automatically shut down.

Ample underdrain capacity is necessary for rapidly discharging effluent and providing adequate ventilation. Channel underdrains should have no more than 50 percent of the cross-sectional area submerged at peak flows. Ten States Standards specify a 10 percent slope on underdrains and a minimum velocity of 2 feet per second at the average daily filter application. Outlet piping should be carefully designed to insure that downstream obstructions will not prevent underdrains from working properly. Provisions should be made for flushing underdrains. In small filters, the use of a peripheral head channel with vertical vents is acceptable. Underdrain inspection facilities should be provided.

Ventilation of the trickling filter bed is required to provide oxygen for aerobic decomposition of the soluble BOD. Natural ventilation occurs due to the difference between the wastewater temperature and the ambient air temperature. This air flow requires adequate underdrains or openings in the filter sidewalls. Synthetic media is often placed on columns allowing a 2 to 3 foot opening around the bottom for ventilation. Forced ventilation may be required when filters are located below grade, if filters are greater than 20 feet deep, if they are subjected to a heavy organic loading, or if covered filters are used. Forced ventilation is normally designed for an air flow of 1.0 cfm/ft^2. However, it should be adjustable to as low as 0.1 cfm/ft^2 for winter operation.

Final clarifiers are required to remove sloughed solids from the trickling filter effluent. Low rate systems are commonly designed with maximum surface overflow rates of 1000 gpd/ft, while high rate systems are designed at 800 gpd/ft. Clarifier size can be optimized with a solids flux analysis on a similar trickling filter operation.

Trickling filters typically yield 500 to 750 pounds of settleable solids per million gallons of wastewater. Depending on the organic loading, the solids will concentrate to 0.5 to 7.0 percent by weight in a final clarifier. Normally, the sludge is pumped to the primary clarifiers or directly to an anaerobic digester. Intermittent solids removal is useful and will allow maximum sludge concentration. This can best be accomplished by a positive displacement pump and a timer.

Provisions should be included for feeding chlorine to the filter influent and polymers to the filter effluent. The chlorine can be used for controlled sloughing to eliminate odors. The polymers can be used for controlling dispersed growth that may arise from toxic industrial wastes or organic overloads.

Ice formation on the media surface is a common problem in cold climates. However, there are several design considerations that can reduce the potential for icing. In a two-stage system, the second stage is more subject to icing, as the second-stage filter influent is colder than the influent to the first stage. If two-stage filters are designed to operate in parallel during cold weather, this problem can be alleviated. By specifying adjustable orifices and splash plates on the distributor arms, a thicker spray can be used to prevent ice formation. Icing along filter walls is particularly common. If the dump gates at the ends of distributor arms are designed to provide a stream rather than a spray to the outside wall, then the wall can be prevented from getting too cold. A strategically placed windbreak can also reduce icing at the filter walls.

III. ROTATING BIOLOGICAL CONTACTORS

The rotating biological contactor (RBC) is a fixed film process employing a series of closely spaced plastic disks attached to a rotating shaft. Approximately 40 percent of the disk is submerged in a reservoir partially filled with influent wastewater. As the disks rotate through this wastewater, a layer of microbial slime builds up on the surface of each disk. The microorganisms utilize the soluble organics in the wastewater for metabolism and the disks aerate and mix this influent waste. As slime builds up on the disks, it is sheared off in the reservoir and wasted to a sedimentation basin.

The media of which the disks are composed, is usually constructed of high density polyethylene sheets. Various manufacturers either corrugate, waffle or dimple the media to obtain useful surface densities ranging from 30 to 60 sq ft/ft^3 of media. The media is attached to a rectangular shaft through either a heat molded hub on the shaft ends or a structural steel spider dispersed throughout the shaft. The shaft is supported by bearings on either end. It is rotated by a mechanical drive system on one end or with low pressure compressed air.

RBC's are normally used for soluble BOD removal in secondary treatment, or for nitrification and denitrification as a tertiary process. They have also been used for upgrading existing treatment plants.

Rotating biological contactors have a number of advantages that render them competetive with trickling filters and activated sludge. Energy requirements of RBC's are lower than activated sludge (400 KWH/MGAL vs. 640 KWH/MGAL, respectively). Maintenance costs are relatively low, since the shaft rotates at approximately 1.5 rpm, reducing wear on mechanical components. In general, EPA cost data has indicated that the RBC process is cost competitive with both activated sludge and trickling filters over a 20-year life span.

Operational factors can make the RBC an attractive alternative to the other forms of secondary treatment. Since 95 percent of the microorganisms are attached to the shaft, RBC's are not easily susceptible to washout. There are no process decisions, such as sludge retention time or recycle rate, to be computed. Studies have indicated that RBC's provide stable treatment and appear to be capable of handling shock loads. Finally, there is very little headloss through the RBC system, which makes it excellent for upgrading existing treatment plants.

Microorganism/wastewater contact for the RBC (30 to 60 minutes) is intermediate between the trickling filter (1 minute) and activated sludge (4 to 6 hours). The mixed liquor in an RBC is normally much less concentrated than is activated sludge. This, coupled with the fact that the sludge does not have to be recycled, greatly reduces the flux on the final clarifier. Additionally, the low MLSS concentration results in discrete particle settling. RBC sludge also tends to be stringy and large. Therefore, this material is not affected by the surface chemistry that influences activated sludge.

A disadvantage of the RBC is that it is capital intensive. Thus, the process generally has higher front-end costs than competitive modes of treatment. It has been found that the disk media may crack when exposed to wastewater temperatures in excess of 90 degrees F.

A lack of process control variables makes operation easier; however, it means that the operator has little control of the system if an upset occurs. There are very few established techniques for controlling treatment by RBC's under overloaded conditions. Sloughing and sludge age of the biomass are uncontrolled parameters.

Like trickling filters, the disk organisms are very sensitive to cold and the process must be covered to insure effective treatment during the winter. Poor aeration of the wastewater reservoir has been observed in a number of systems.

RBC's have a high rate of sludge production. Although the SRT on the fixed film is relatively high, sludge yields can range from 0.1 to 2.0 lb/lb of soluble BOD_5, or from 0.3 to 0.5 lb/lb of total BOD_5. Additionally, there is relatively little reduction of incoming organic solids. These factors must be considered in the design of sludge handling equipment.

A comparison of activated sludge, trickling filters and RBC's is presented in Table 13.4.

Design of an RBC treatment system is best accomplished using the results of pilot plant studies. This becomes essential for industrial waste treatment. Figures 13.1, 13.2 and 13.3 show RBC design data from two manufacturers for secondary treatment of municipal wastes. Figures 13.4 and 13.5 show design data for nitrogen removal using nitrification RBC's. Some manufacturers use media with increased surface areas for nitrification shafts. The designer should be confident that no significant carbon leakage will carry over to the high density nitrogen disks. This could result in a biomass overload and structural failure. Submerged RBC's have been used for converting nitrate to nitrogen gas. Figures 13.6 and 13.7 show the Autotrol method for this process. Methanol must be added at the rate of 3.0 lb of methanol per lb NO-N dentrified. Additionally, there must be 3.0 lb $CaCO_3$ alkalinity per lb NO_3-N reduced.

Pretreatment of incoming wastewater is necessary to prevent damage to the disks. The most important form of pretreatment is removal of trash solids which may become trapped between disks. Where primary clarifiers are not used, a tight screen or a mechanically cleaned grit chamber is recommended.

Figure 13.8 represents one manufacturer's recommended overflow rates for secondary clarifiers. Sludge recycle is normally not included. Sludge drawoff from the bottom of the clarifier can be continuous or intermittent. Positive displacement pumps, such as diaphragm pumps or progressing cavity pumps, are recommended for drawoff. The pump speed can be used for metering sludge flow.

Even though control over the RBC treatment process is limited, there are a number of options which the design engineer should consider to increase flexibility of operation. For instance, air drive was originally proposed as a means of simplifying the drive system. However, it appears that air drive can be used to solve other problems encountered with RBC's. In certain treatment situations, especially when wastewater temperatures are above 90 degrees F, the microbial slime may not easily slough. Buildup of this material can continue until damage to the disk occurs. Air drive, under these

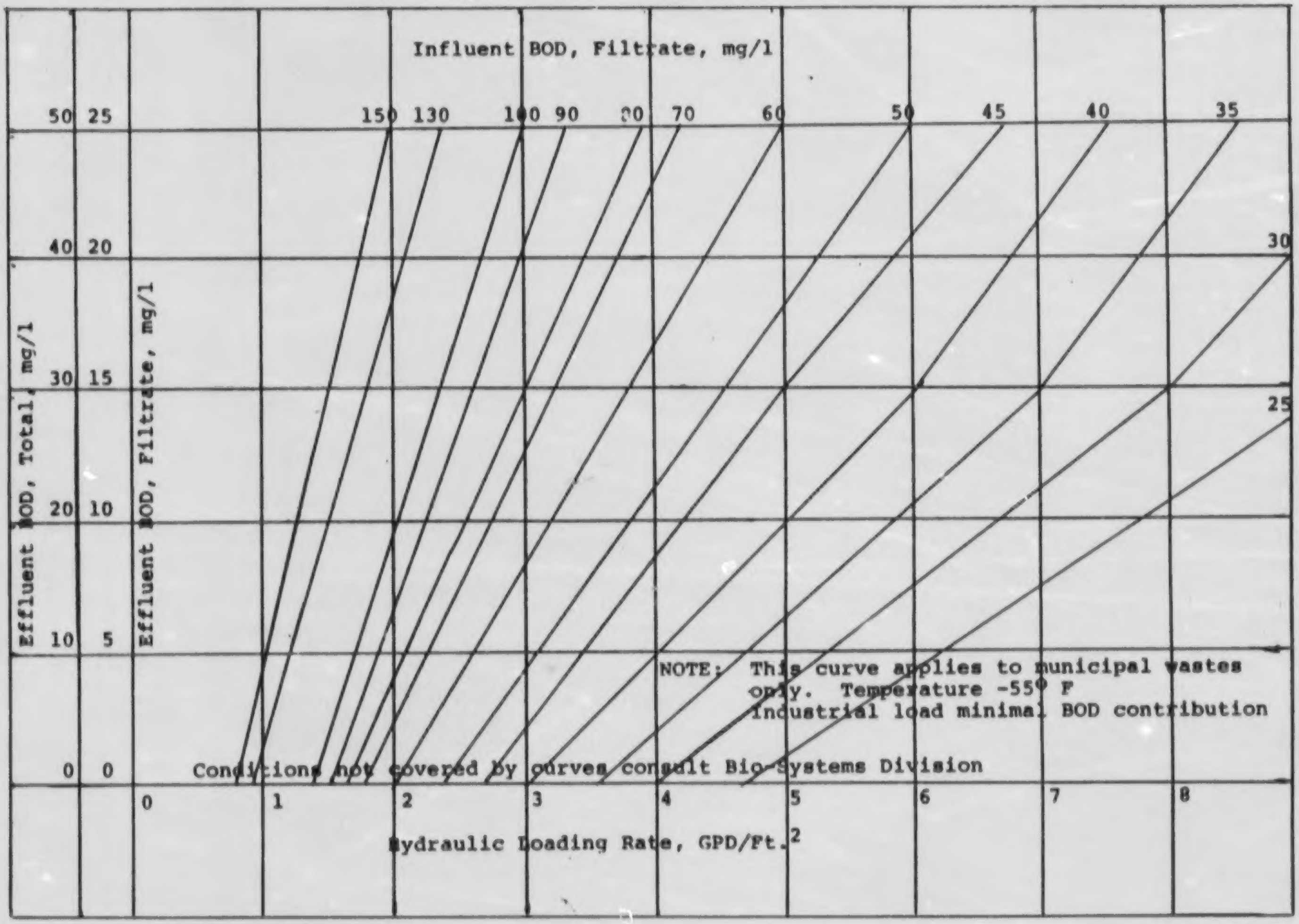


FIGURE 13.1 AUTOTROL DESIGN CURVES FOR DOMESTIC BOD REMOVAL

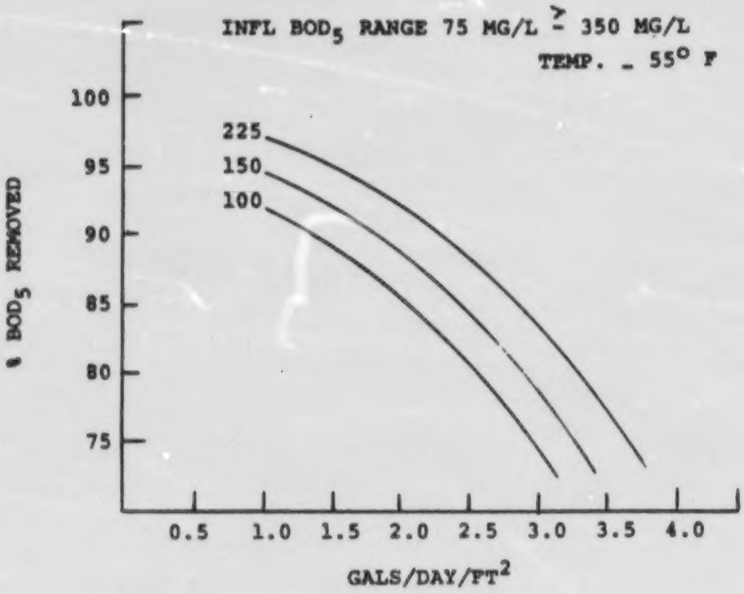
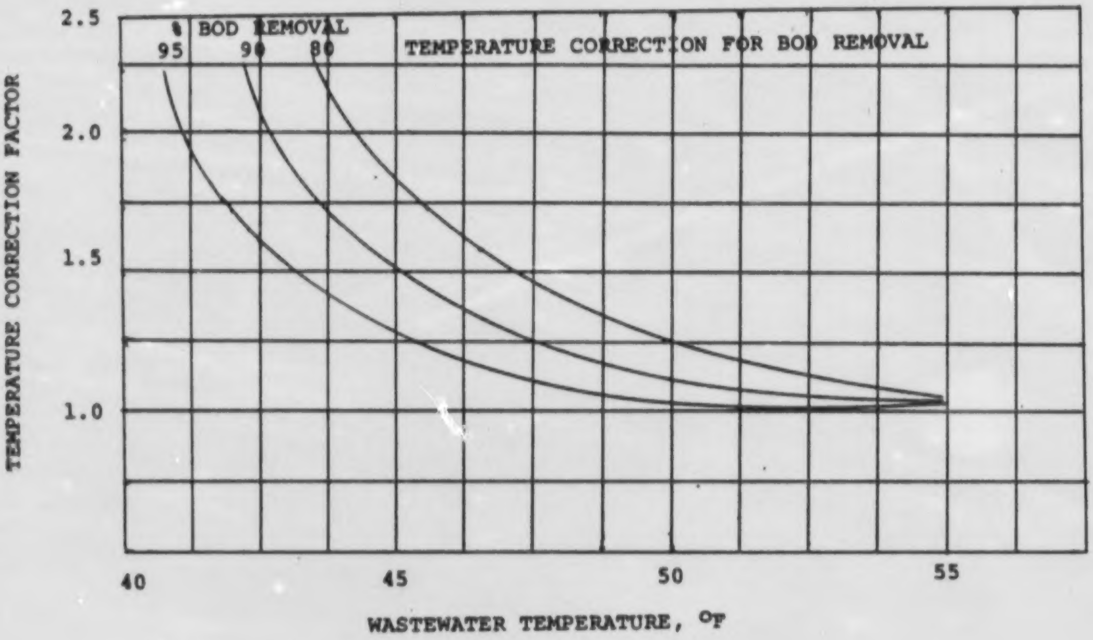


FIGURE 13.2 HORMEL DESIGN CURVES FOR DOMESTIC BOD REMOVAL



Where: $\frac{GPD}{Ft.^2} = \frac{GPD/Ft^2 \ @ \ 55^\circ F.}{}$ at temperatures less than 55° F.

Data was supplied by Autotrol Corporation

FIGURE 13.3 TEMPERATURE CORRECTION FOR BOD REMOVAL

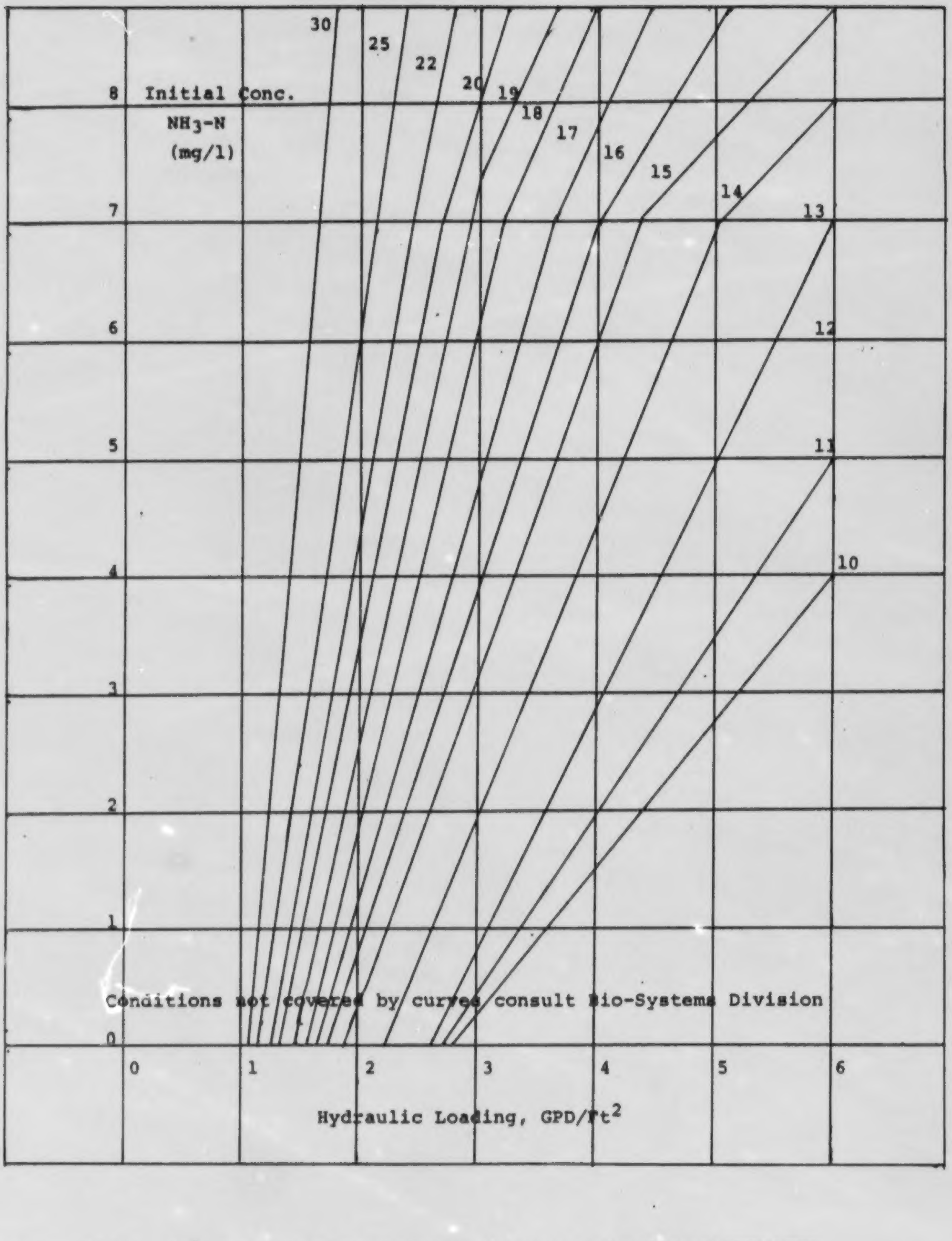


FIGURE 13.4 BIO-SURF PROCESS NITRIFICATION OF DOMESTIC WASTEWATER

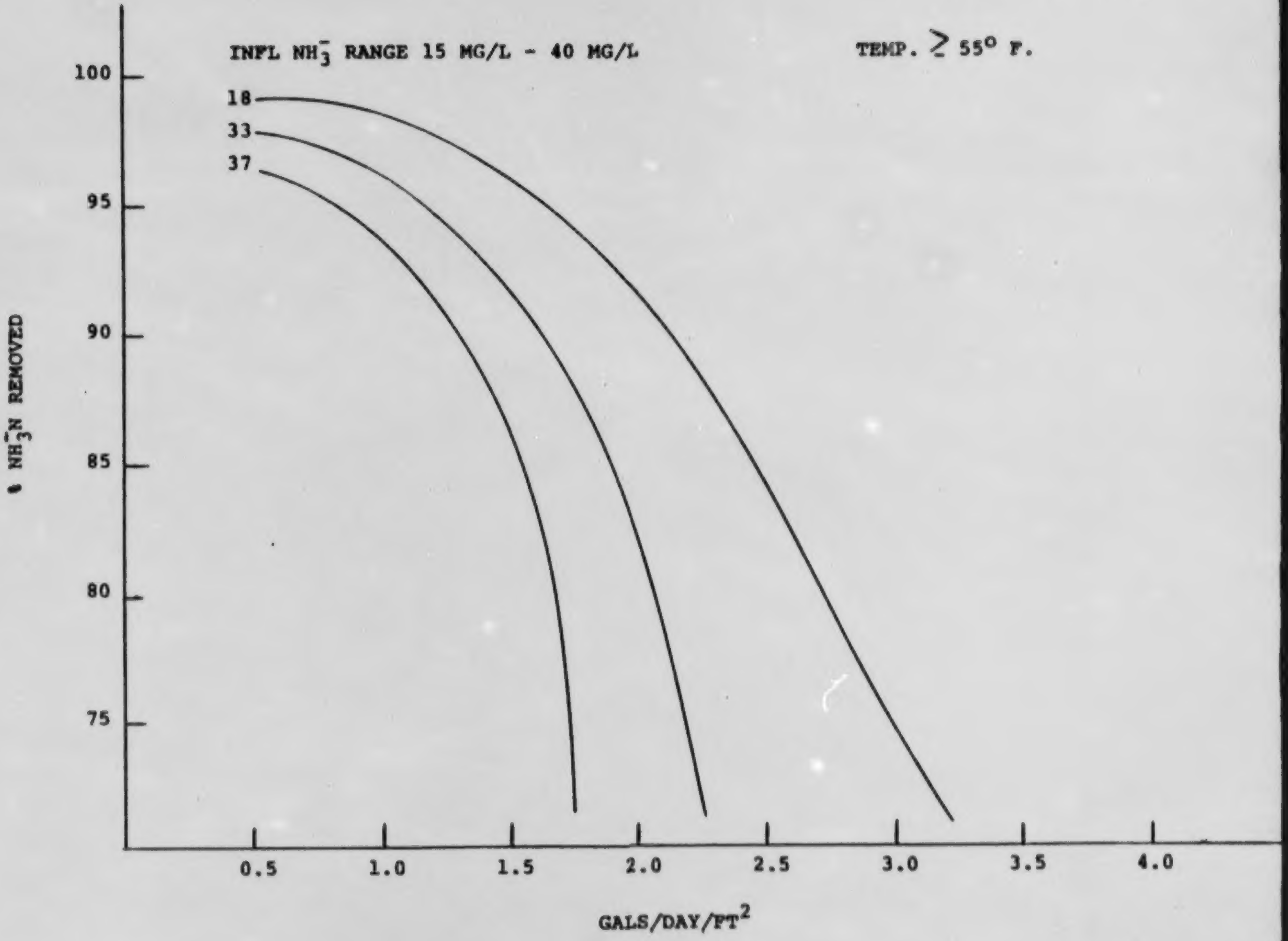


FIGURE 13.5 HORMEL DESIGN CURVE FOR DOMESTIC NITRIFICATION

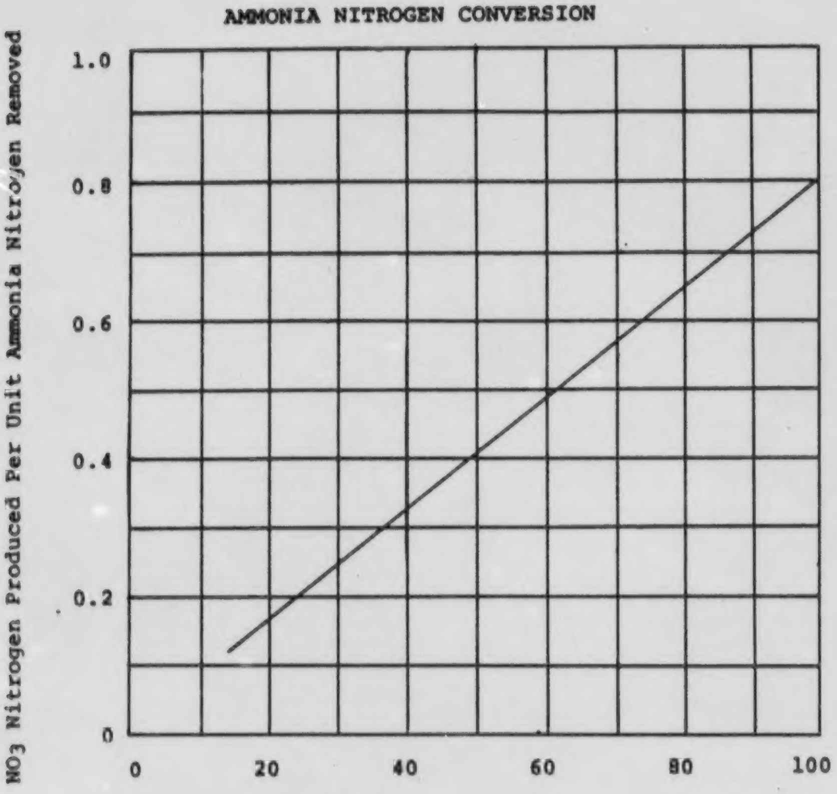


FIGURE 13.6 NITRATE-NITROGEN VS. AMMONIA NITROGEN REMOVAL

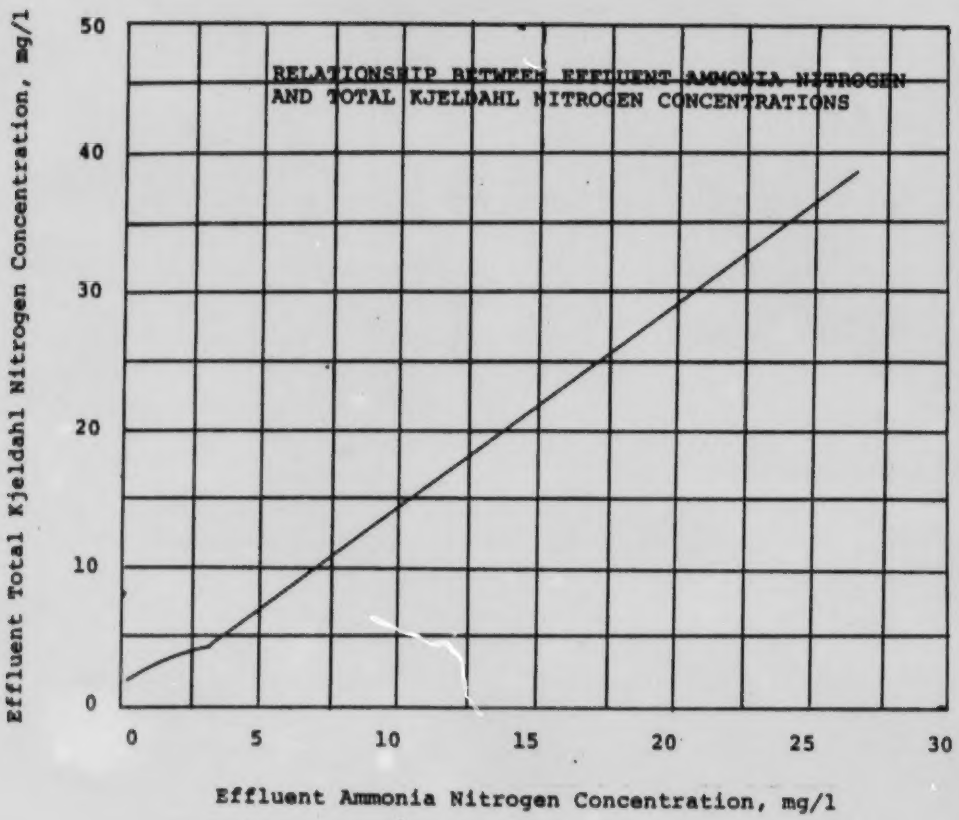


FIGURE 13.7 EFFLUENT AMMONIA VS. KJELDAHL NITROGEN

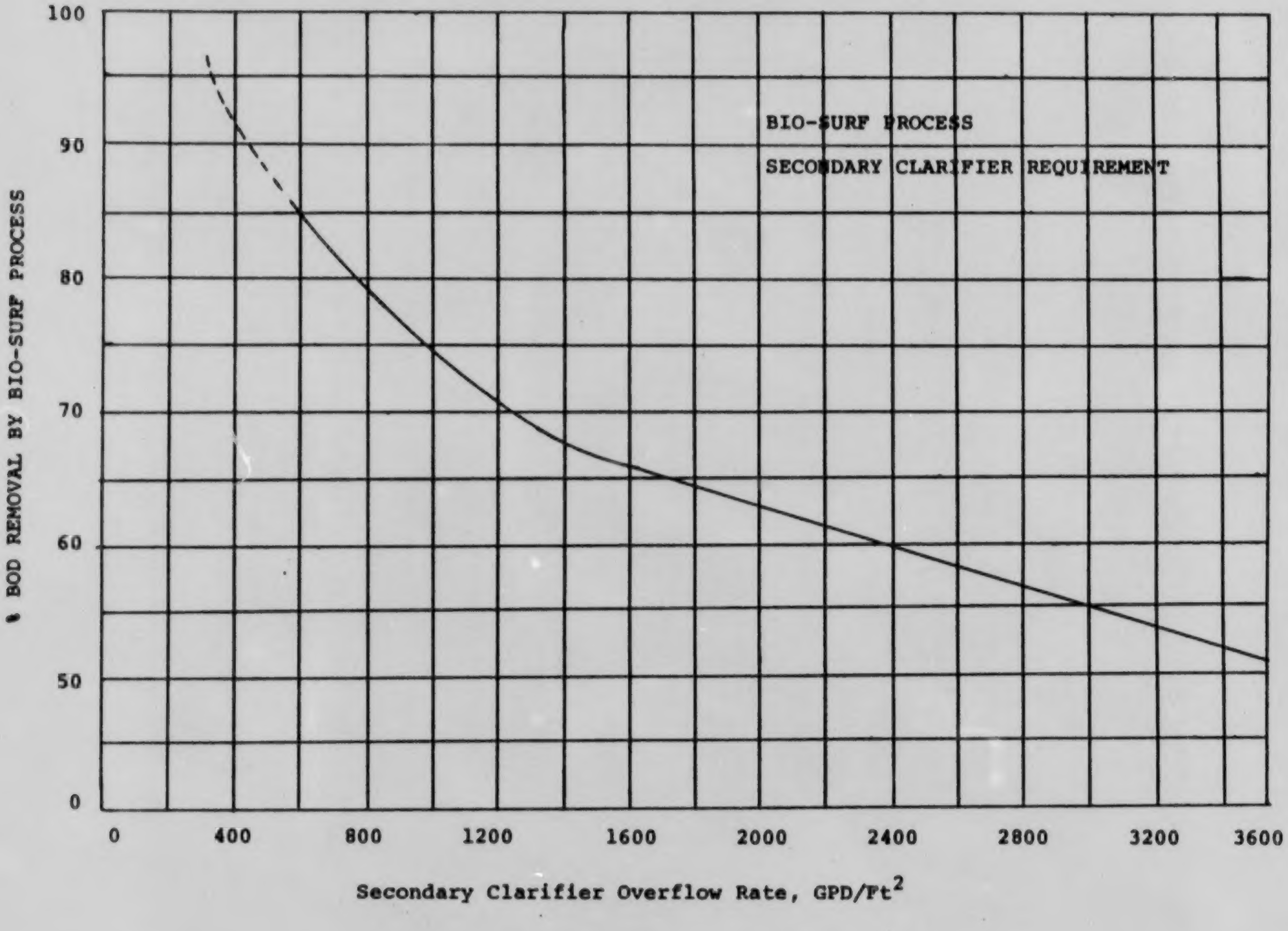


FIGURE 13.8 BIO-SURF PROCESS SECONDARY CLARIFIER REQUIREMENT

TABLE 13.4

COMPARISON OF SLURRY AND FIXED-FILM BIOLOGICAL PROCESSES

Characteristic	Activated Sludge	Biodisk	Trickling Filter
Operator skill required	High	Medium	Low
Control strategy	SRT	Self-regulating	Self-regulating
Controllable parameters	SRT & F:M through sludge wastage recycle rate, oxygen supply	Contacting pattern & biomass loading	Hydraulic loading
Data required for control	MLVSS, effluent VSS, underflow solids influent flowrate, wastage rate	None	None
Waste sludge concentration	0.5 - 2 percent	3 - 5 percent	3 - 5 percent
Sludge reduction (lb/lb BOD_5)	0.3 - 0.5	0.2 - 0.4	0.2 - 0.4
O_2 transfer (lb O_2/hp-hr)	1 - 3	3 - 7	---
Hydraulic retention time (hrs)	5 - 24	1 - 2	0.2 - 0.3
Primary operating problems	Solids - liquid separation including bulking and dispersed growth, foaming	O_2 limitation in highly loaded stages, failure	O_2 limitation, clogging, "filter flies"

circumstances, will provide additional turbulence and aid sloughing. Oxygen transfer in full scale systems has been poorer than pilot scale testing would predict. Low DO in the mixed liquor can result in the discharge of colloidal material in the effluent. Air drive bubbles from compressed air in the wastewater reservoir increase the DO levels.

Flexibility of operation can be enhanced by providing the capacity for varying rotational speed between 1.0 and 2.0 rpm. This will permit the operator to adjust the rate of rotation to maintain a DO of between 1.0 and 2.0 mg/L in the reservoir. Rotational speed can be used for equalizing temperature if there is a differential between the ambient air and the wastewater. Higher rotational speed can improve mixing and the food-to-microorganism contact.

If anaerobic conditions are anticipated in the RBC influent, then preparation, step feed or hydrogen peroxide addition should be considered. An anaerobic feed can cause white filamentous growth on disks and colloidal carryover to the clarifiers. These conditions can be caused by overloaded first-stage RBC.

If first-stage BOD loadings of greater than 5.0 lbs/thousand ft^2 are anticipated, it is desirable to be able to transfer feed to the second or third stages. This capability will increase operating efficiencies during periods of treatment upset. Step feed can be achieved by separate piping or pulling bulkheads between stages, allowing interstage mixing and equalization of load.

The RBC is poorer at handling transient loads than activated sludge. Pilot studies have shown that, although the RBC will recover from shock loads faster, more of the transient load will pass through the system. This is probably due to the shorter detention time in the RBC than in activated sludge. Experience has shown that transient loads will remain untreated if organic peaks are greater than twice the average daily load. If shock loads are commonplace, then some means of surge protection, such as equalization, should be designed into the plant. Equalization of influent will help prevent excessive loss of biomass from the disks if toxic substances are contained in the wastewater. A treatment upset can result in filamentous growth and dispersed growth carryover into the clarifier. Therefore, provisions for feeding polymers to the biodisk effluent should be designed into the treatment system.

IV. STABILIZATION PONDS

A stabilization pond is an earthen basin of controlled shape and depth which is designed to treat wastewater. Ponds have become very popular in small communities because their low construction and operating costs offer a significant financial advantage over other treatment methods.

Stabilization ponds are classified according to the type of bilogical activity that is taking place within them. There are three recognized classes of ponds: aerobic, facultative and anaerobic. Aerobic ponds are shallow enough (5 feet deep or less) to allow sunlight to penetrate to the bottom. This allows algae to proliferate and release oxygen throughout the entire pond volume. Facultative ponds have three distinct layers. The surface layer contains algae and aerobic bacteria; the bottom layer is devoid of oxygen, and here anaerobic decomposition of organic compounds takes place; the middle zone is partly aerobic and anaerobic, and facultative bacteria decompose waste. Anaerobic ponds are deep (up to 20 feet) and are characterized by low surface area-to-volume ratios and high organic loadings. Stabilization is brought about by a combination of precipitation and anaerobiosis.

Pond efficiencies are temperature dependent. As such, design decisions such as series or parallel flow, storage capacity and intermittent or continuous discharge may depend upon climate conditions in an area. The effect of climate on seasonal discharge strategies is discussed in WPCF, Manual of Practice No. 11, "Operation of Wastewater Treatment Plants," 1975.

In order to prevent short-circuiting, ponds should be rectangular in shape. For flexibility, there is an advantage for facilities that permit operation at selected depths of up to 5 feet. Provisions for additional depth may be desirable at large installations or ponds over 30 acres.

The soil that serves as the pond bottom must be relatively impermeable. Porous soils should be sealed with clay or asphalt. There should be freeboard of two feet from the top of the dike to the high water level.

Wastewater should be fed to the cells with adequate velocities to assume self cleaning of the distribution piping. The piping and inlet control structures should be such that individual cells may be operated in series or parallel to allow flexibility of operation. Inlets should be submerged and terminate over a concrete pad. For small ponds, a center inlet is preferred; for ponds of 10 acres or more, the inlet can be installed approximately 400 feet from the dike; for large facultative ponds, multiple inlets (preferably movable for flexibility) are desirable.

The outlet control structure should provide control of pond depth and rate of discharge. The discharge pipe to the receiving waters should be submerged. The outlet structures should permit variable-depth operation and effluent discharge from any desired depth. The control should make it possible to maintain a different water level in each cell when they are operated in series. The ability to completely drain the pond is desirable. A gauge stick permanently attached to the outlet structure is recommended to monitor pond levels.

Collection of samples and flow monitoring should occur at the points indicated in Table 13.5.

TABLE 13.5

SAMPLE PARAMETERS AND LOCATIONS IN STABILIZATION PONDS SYSTEMS

	Location		
Parameter	Influent	Pond	Effluent
Temperature	X		
Flow	X		X
pH		X	
DO		X	
Cl			X
BOD_5	X		X
SS			X
Fecal Coliform			X
Nitrogen			X

A continuous flow measuring station using a "V" notch or Cippoletti weir and a float-activated recorder is recommended on both the plant influent and effluent.

An inexpensive microscope should be supplied to the lab. The microscope will help an operator identify the condition of the system. The presence of blue-green algae or filamentous organisms can indicate a low pH, DO or nutrient problems. The presence of various protozoa, such as Daphnia and Paramecium, can indicate low loadings or proper stabilization in secondary cells.

Operational flexibility is best realized by designing for pond operation in several different modes. Multipond systems should have the capacity to run either in series or in parallel. Each pond should have at least three distinct drawoff depths provided at the outlet structure. The inclusion of interpond transfer pipes will give the operator flexibility to redistribute pond volumes if he so desires. Good pond operation requires the capability of filling and drawing the final cell to control algae and to permit discharge when the operator deems it appropriate.

UNIT PROCESS DESIGN - OTHER FACTORS

UNIT 14

SAFETY

UNIT 14a

UNIT 14a - SAFETY

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- Justify the reasons for including basic safety necessities and requirements in designing or redesigning wastewater plants.
- Identify the kinds of personal safety considerations which should be considered in plant design.
- Identify available sources for information concerning current safety regulations and standards for plant design.
- Design/redesign wastewater plants which meet basic safety requirements and conditions and provide optimum safety for plant operators.

UNIT 14a - SAFETY

I. INTRODUCTION

In the past, the design of wastewater treatment plants generally has neglected safety considerations. The wastewater and disposal industry, according to National Safety Council accident frequency statistics, is considered among the most hazardous industries in the United States.

Failure to consider safety features is so common that often newly completed facilities must be immediately remodelled to deal with safety hazards.

Safety consideration should be fundamental to each stage of the design of a plant. This is necessary not only to reduce personal injuries, but to avoid needless shutdowns and repairs and the costs they involve.

The primary objective of this unit is to encourage the Design Engineer to thoroughly research the safety aspects needed in the design of a new facility or the modification of an older one. This can best be accomplished by the engineer consulting with operating personnel and those personnel responsible for the safety engineering criteria of the facility.

II. DESIGN STANDARDS

All recommendations that will be discussed here are items that have been researched and listed in the Water Pollution Control Federation Manual of Practice, MOP 8 "Wastewater Treatment Plant Design."

Other sources of help are the National Safety Council, particularly the Water Service Division of the Public Employee Section of the Council and its member agencies, Bureau of Standards, etc. Additionally, specific design criteria that have been utilized in specific facilities will be presented.

The majority of these design considerations are those recommended or required by the Occupational Safety and Health Act. In many instances, treatment plants or facilities are not required to conform with OSHA standards in their present format; however, since OSHA standards have been formulated primarily from existing standards such as ANSI, BU Mines, National Electric Code, etc., this design criteria is still of value to the design engineer.

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III. DESIGN CONSIDERATIONS

A. General

- Separate Mechanical Forced Ventilation. Some operations will require continuous ventilation. Areas where there should be separate mechanical forced ventilation systems, and possibly automatic clock operations, are influent rooms, wet wells, dry wells and screen or comminutor rooms, etc.

- Separation of Facilities. This concerns the separation of wet wells, for instance in the screen or comminutor rooms, from other facilities. Consideration in this area should be given to separate access facilities.

- Pump Stations. Pump stations should be equipped with a superstructure to facilitate personnel entry and ventilation and to provide a natural source of light.

- Forced Ventilation Systems. Forced ventilation systems should be designed to force fresh air into wet wells so that the exhaust ventilator does not "pull in" sewer gases or other nauseous fumes from influent fume lines discharging to the wet well.

- Open Channel. Open channels should be provided immediately ahead of waste flow entry to influent structures to provide for the ventilation of explosive gases or vapors.

- Grit Chambers. Grit chambers should be provided with adequate ventilation to prevent the accumulation of explosive gases or vapors.

- Chlorination Facility. Chlorine evaporator and chlorine storage rooms should be separate and located above ground. Egress from these rooms should only open to the outside atmosphere. Chlorine evaporator and chlorine storage rooms should be provided with view windows to provide observation from the outside prior to any personnel entry. Liquid chlorine containers, such as one ton units, should be stored in well-ventilated, fire-proof structures with protection against direct exposure to the sun.

- Automatic Ventilation. Forced mechanical ventilation should be actuated automatically by light switches at such locations as chlorination rooms, chemical handling room, laboratories, etc.

- Ventilation Exhaust. Duct work should be adequately located to distribute air. There should be no contamination of air inlets to other areas where spaced ventilation is utilized. A minimum of 15 complete air changes per hour is recommended and systems should be designed for this minimum capacity.

- Light and Ventilating Switches. Light and ventilating switches should be located outside the chlorination rooms or storage chemical rooms. An additional feature in this area would be the installation of photoelectric controls to actuate ventilation and lighting when the light beam is interrupted into such a room.

- Special Test Areas. Additional ventilation with explosion-proof motors should be provided in test areas of laboratories and laboratory hoods.

- Hood and Room Exhaust Systems. Design should be concerned with the balance of these systems so that negative pressure is not created within the hoods. Separate ventilation to each hood should be utilized.

- Storage Area. Separate storage areas for dangerous chemicals should be part of the plant design. These storage areas preferably should be remote from existing facilities in common use and should be protected from the elements.

- Dust Collectors. Effective methods for the removal of dust, fly ash and soot discharged from stacks should be provided. Dust collectors should be considered in those areas where needed.

- Incinerators. Methods to handle dry pulverized sludge to preclude dust accumulation that could result in potential dust explosion hazards should be considered.

- Shop Areas. Exhaust systems should be designed for facilities containing such operations as permanent welding units.

- Sludge Storage Tanks. Sludge storage tanks should be located upstream of vacuum filters. Again, they should be designed with all possible safeguards against buildup of toxic and explosive gases.

- Sludge Pumps. Sludge pumps should be designed with pressure gauges to indicate a buildup of gases when the pumps are out of service. Sludge pump areas should be naturally ventilated and, if necessary, mechanically ventilated, in a manner similar to that for wet wells.

- Gas Protective Devices. Gas protective devices should be incorporated into digesters, strictly in accordance with manufacturer's recommendations.

- Automatic Gas Alarms. Automatic gas alarms, both visual and audible, should be designed to detect explosive and/or combustible gases or vapors and be able to shut off all power in the area being protected, except for emergency and explosion-proof ventilating and lighting equipment.

Additionally, these systems should be equipped with remote read-out to operating or control facilities. Such alarms should be located in the screen or comminutor room, digester area, grit chambers and other sensitive areas where needed.

- Chlorine Leak Detection Systems. Chlorine leak detection systems should be installed to signal equipment failure and to provide automatic "fail-safe" shut off flow of chlorine to evaporators and/or chlorinators. Again, such detection devices should be transmitted to a control station to assist in actuating emergency procedures.

- Piping. Both influent and effluent pipes to sludge pumps should be valved so that if pumps are dismantled for maintenance, sludge and gases cannot enter the work area.

- Sampling Valves. Sludge pumps should be provided with quick closing type sampling valves.

- Wash Down Facilities. Wash down facilities for cleaning purposes should be provided whenever there is a possibility of sludge spillage. Additionally, emergency shower and eyewash stations should be located in these areas. Adequate drainage should be provided for all chemical storage and working areas. The layout of such drainage should assure that dissimilar chemicals or foreign materials are not mixed together.

- Corrosion Preventatives. Piping, storage tanks, etc., should be coated to prevent or retard corrosive action.

- Emergency Equipment. Pull chain or, preferably, pedal operated showers with chest-high level wash spouts and floor drains should be provided in all areas where chemicals are being handled or stored.

- Hazardous Areas. The designer should consider the use of portable ladders, rather than manhole steps, in many areas to discourage easy entry.

- Incinerator Controls. Automatic shutdowns to terminate the flow of hazardous waste materials to the incinerator should be provided in the event of a flame out. Automatic ignition start controls should be provided for all incinerator installations. Waste gas burners and vents should be located a safe distance from inhabited buildings or other combustible facilities. Controls for the incinerator burner system should assure adequate purge time and interrupted pilot, flame scanner and safety controls to prevent the possible igniting or re-lighting of a burner in a potentially hazardous atmosphere.

- Disinfection Systems. Disinfection systems should be selected to minimize handling and transportation problems.

- Corrosive Liquid Chemicals. Liquid ferric chloride, sulfuric acid and other corrosive chemicals should have acid-proof pumping equipment permanently installed for pumping to the point of application.

- Gas Outlets. Gas outlets used in laboratories should be equipped with substantial handles and they should be clearly identified; i.e., labelling, color-coded, etc.

- Dry Hypochlorite. Facilities should be designed to store this chemical in a cool, dry, well-ventilated area.

- Chemical Handling. Materials and devices used for the storing, transporting or mixing of hazardous chemicals should be designed to be compatible with the chemical involved.

- Dikes or Curbs. Dikes and curbs should be designed around tanks capable of holding a stored volume of the particular tank, plus a safety factor of 25 percent in each liquid chemical storage area.

- Safety Equipment. Safety equipment should include portable ventilation equipment, such as air blowers and adequate lengths of non-collapsible ducting; hydrogen sulfide, methane, chlorine, carbon monoxide, and oxygen deficiency indicators; industrial type vacuum cleaners; chlorine emergency repair kit; and proper self-contained air breathing apparatus, as well as protective clothing.

B. Facilities

- Fencing. Fencing should be provided around all plant structures and plant operations where unauthorized entry could result in personnel mishap or disruption of plant operation. These fences ideally should be equipped with adequate lighting for after dark.

- Laboratory Equipment. Laboratory sinks, toilets and wash sinks should be pedal operated.

- Shower Facilities. Shower facilities with hot and cold running water and adequate drainage should be provided in the employee locker rooms.

- Food Service. Cafeteria, dining rooms, etc., should be separated from all other facilities.

- Lockers. A minimum of two lockers for each plant employee should be considered (one for work clothes and another for street wear). Also, lockers should be designed with angled tops to prevent the placing of objects on the top that could fall or be dislodged, thus causing personal injury.

- Washing Machines. Automatic wash machines and dryers should be provided for the washing of work clothes.

- Disinfectant Dispensers. Disinfectant dispensers should be located in shower rooms and wash rooms to be used by all employees.

- Potable Water Supply. Where potable water is used by plant personnel or for other purposes, such as washdown of equipment, it should be protected by backflow preventers or air break discharge.

- Non-Potable Water Outlet. These systems should be color-coded with warning signs indicating that they are non-potable water outlets and that the water is definitely not safe for human use.

- Conveyor Belts. Several manufacturers now make conveyor belts with sloping sides to prevent spill-off of material carried on the belts.

- Insect Killers. These electronic units should be considered for areas such as grit chambers, sand filter building and other areas where insects are a nuisance.

- Bird Repellers. In areas where concentration of birds can be a problem, installation of ultrasonic repellent equipment is recommended.

- Access Doors. Access doors leading to the outside from all facilities should be equipped with panic hardware. Doors from hazardous areas should be tight-fitting, self-closing to open out and equipped with panic bars. Laboratories and basement areas should have two easily reached exits reasonably remote from each other. Interior doors, where appropriate, should swing both ways and have wire glass or Lucite panels.

- Glazing Material. The use of unbreakable material, such as Lucite or acrylic, in lieu of glass is recommended.

- Ground Fault Interrupters. Ground fault interrupters should be designed into systems for receptacles using power tools, lighting, test equipment, etc.

- Take-up Reels. Installation of take-up reels, preferably of the automatic type, are recommended for such equipment as welding cables, wash down hoses, portable air lines, electric power cords, etc.

- Ramps. Thought should be given to the use of ramps with non-skid treads, rather than stairs, wherever feasible.

- Door Check. Fire systems or door checks should be installed on all doors to assure that doors remain in a closed position at all times.

C. Environmental

- Personnel Protection. Personnel protection provisions should be included in the design to afford protection against infrared radiation from combustible units, and ionization radiation from radioactive substances.

- Noise Reduction. All equipment should be designed to achieve the most effective noise reduction possible. Air compressors, vacuum pumps for filter units, centrifuges, blowers, standby power units, and other similar equipment producing high noise levels should be located either in isolated buildings or rooms, or within acoustically sound-proofed structures for maximum sound reduction.

- Lighting. Adequate lighting should be provided throughout the plant. Areas of operational activities and particularly those areas involved in the repair and servicing of equipment and controls should be extremely well lighted. Exterior floodlighting should be provided for night time operations and maintenance, as well as for inspection and for general illumination of plant operational areas. The design of lighting poles should be such that they are accessible for maintenance. Emergency battery operated lights should be provided for interior areas, critical operating and control areas, and particularly in the vicinity of stairways and exits, elevators, etc. Greater consideration should be given to the use of fluorescent, rather than incandescent, light. Luminous paint should be considered for labelling as it is visible for some time after power failure.

- Hand Lift Trucks. Hand lift trucks should be considered for use in chemical handling or in handling other equipment.

D. Physical Safety

- Fire alarms should be located at the plant and automatic firefighting systems installed. Firefighting devices should be located in each separate structure at accessible points near the entrance to areas of likely conflagration.

- Laboratory wall surfaces, ceilings and furniture should be made of fire-resistant materials with cove bases.

- If oxygen is used for activated sludge aerators, provide protectors at points of possible leakage from supply tanks.

- An emergency power supply for critical lighting and ventilation should be available.

E. Burns

- There should be cages or guards around accessible hot exhaust piping.
- Acid-proof pumping equipment for liquid ferric chloride, sulfuric acid, or other liquid chemicals should be permanently installed.

F. Explosions

- Entry ways for the rooms holding a gas or oil fired heat exchanger should satisfy safety requirements.
- The wet well should be located either in a separate structure or accessible only from the outside.
- Standby engines used for emergency electrical power should be housed in separate structures.
- Explosion-proof motors, switches, lights and wiring should be provided in screen area, grit chamber, wet well, digester area, laboratories, sludge pumping area, and wherever explosive gases may be present as a result of accident or malfunctions.
- Switches, electrical equipment, and wiring associated with the wet well should be located in a non-hazardous area, if at all possible.
- Safety equipment should include an explosion-proof flashlight and safety tools (non-sparking).
- Safety harnesses should be available at vaults or pits containing potentially harmful or explosive gases.
- Digesters should have pressure relief valves.
- Sediment and drip traps should be installed at low points in the gas system.
- Waste gas burners should be located in an open area for ease of observation.
- The gas collection system should be designed to segregate as much of the piping and appurtenances as possible.

G. Electric Shock

- All electrical wiring should be properly insulated, grounded and unexposed.
- Control circuit voltages shouldn't be over 120V, if possible.

- All medium and high voltage cables should be completely enclosed in either conduit or covered tray and adequately marked to warn personnel of contents.

- Switchboards should have a "dead front" and "dead rear." In moist areas, where there is a possibility of flammable gas accumulation, enclosures for switches, equipment and light should be moisture- and explosion-proof.

- There should be electrical "lock-out" facilities to prevent accidental starts when machinery and equipment are being worked on or otherwise taken out of service.

- An emergency shutoff switch, clearly labelled, should be at all machinery units.

- Indoor control panels should be well ventilated.

H. Falls

- There should be rest landings on stairways. Tall ladders should have rest or offset landings. Fixed ladders more than one story high should have safety cages.

- Stair risers should be of equal height and proper slope. Ramps should have a pitch commensurate with intended use.

- Landings and stairs should have non-slip treads.

- There should be a separate handrail where entrance is provided by ship's ladders or manhole steps. Ladder or manhole steps extending above entrance levels should provide a handhold for entering.

- Floors should have non-slip surfaces (such as concrete floated smooth with broomed finish) or added covering. Laboratories should have durable, non-slip floors.

- In cold climates, there should be gratings on outside stairs and walkways around tanks wherever possible.

- Where spillage is a problem, as in sludge pump and vacuum filter areas, sufficient faucets, adequate floor drainage, and water repellent wall surfaces should be provided for cleanup purposes.

- Process tanks should have adequate railings, lifesaving devices, and interior ladders or manhole steps.

- Lift rings and grating locks should be flush-mounted to prevent tripping.

- "Head knockers" such as low pipes, valves, ceilings and suspended equipment should be eliminated.

- A safe method should be available for lamp replacement.

- There should be emergency battery-operated lights for interior areas, particularly in the vicinities of stairways.

- Proper painting will provide a light color in darker areas and distinguish walking areas, including steps, by contrasting colors.

I. Drowning

- Manholes, steps, or permanently attached ladders should be inside of tanks, basins, or wet wells, for entry or exit in cases of emergency.

- Life preservers should be attached to ropes and located near open tanks. Safety poles (pipe poles) should be available.

- There should be provisions for lifelines along the internal walls above the water surface.

J. Impact

- Equipment, piping valves and other appurtenances should be arranged for ease of access: uncrowded and with ample walk areas.

- All commonly used passageway doors should be equipped with Lucite panels to prevent accidental opening into another person.

- Stairways should have kickplates around stairwell openings and adequate railings.

- Hatchway covers should have springs or positive locking devices to hold the covers open (unless they swing free of the opening and lie flat).

- Operations associated with incoming railroad cars should be planned for safety.

K. Rotating Machinery

- There should be adequate space between machinery to permit maintenance in a safe manner.

- There should be cages around exposed rotating shafts and all other moving parts on machinery. Exposed vertical shafts should have guards to safeguard the work from injury by "whipping" if the shaft breaks.

- Shafts should have painted spiral or other markings to indicate running conditions.
- Positive displacement pumps should have an air chamber and a pressure switch that will stop the pump at a pre-set pressure.
- An emergency shutoff switch, clearly labelled, should be located at all machinery units.
- Running equipment should have indicator lights.

L. Materials Handling

- There should be fixed or portable electrical hoists with ceiling lifting devices for lifting heavy loads, including chemicals, pumps, motors and equipment for repair or replacement.
- There should be lifting attachments such as hooks or eyes on heavy equipment.
- Hoists to lower and raise men and equipment into pit areas should be available.

M. Warning Signs by Each Water Outlet

1. Standardized color-coding of process piping and emergency equipment:
    a. Orange-to designate dangerous parts of machines, or energized equipment and flammable gas lines.
    b. Blue - potable water.
    c. Yellow - chlorine.
    d. Black - raw sludge.
    e. Brown - treated sludge.
    f. Purple - radiation hazards.
    g. Green - compressed air.
    h. Jade Green - process or flushing water (non-potable).
    i. Gray - wastewater.
    j. Orange with blue letters - steam.

k. White - traffic and housekeeping operations.

l. Red - fire protection equipment.

IV. PERSONAL PROTECTIVE AND SAFETY EQUIPMENT

Even with the best safety designs, unhealthy and unsafe conditions will be encountered, hence the need for protective and safety equipment. The Design Engineer should assume responsibility for specifying the equipment and its proper placement throughout the facility. He should consider personal protective equipment in the areas of head, ear, face and eye, respiratory, foot and leg, and clothing.

It should be noted that there are various categories of protective respiratory devices with specific applications and limitations in the protection they afford. Respiratory devices are certified by the National Institute of Occupational Safety and Health. The Design Engineer should take care to locate safety equipment so that it is easily accessible in case of emergency. Essential safety equipment includes safety belts, harnesses, life jackets and lifelines. Storage facilities should also be specified for first-aid equipment.

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ENERGY CONSERVATION

UNIT 14b

UNIT 14b - ENERGY CONSERVATION

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- Apply design techniques to reduce electricity consumption.
- Reprogram electricity consumption to reduce peak load penalties.
- Specify pump systems to reduce energy consumption.
- Control air consumption in the activated sludge process.
- Manage plant operation to control energy consumption.

UNIT 14b - ENERGY CONSERVATION

I. INTRODUCTION

In the past, in the design and construction of most municipally-owned wastewater treatment plants, energy conservation was not a major consideration of the Design Engineer. The designer was more concerned with reducing capital costs while maintaining simplicity, reliability and operability. However, recent dramatic escalations in the cost of energy are changing this perspective and designing for energy conservation is now a significant consideration. All aspects of wastewater treatment plant design are currently being analyzed for potential energy saving opportunities. Within a wastewater treatment plant, the most energy intensive treatment operation is the activated sludge secondary process followed by sludge processing. Preliminary, primary and disinfection processes are small users of energy, but even there, potential savings should be looked for and made if possible. In this unit, energy conservation aspects of electricity consumption, hydraulic flow regimes, air consumption in aeration basins, thermodynamic budgets, utilization of digester gas and plant management will be discussed. Also, an example of a solar energy heated plant will be presented.

II. ENERGY CONSERVATION PARAMETERS

A. Electricity Consumption

1. Peak Demand

Utilities frequently have different rates for different types of consumption: one rate based upon KWH consumption, a second upon the power factor or quality of the load, and finally, the peak demand load. To meet peak demands, utilities usually have to have expensive standby generation systems, such as gas turbines which consume critical hydrocarbon fuels, or pumped storage units. To reduce their peak loads, utilities offer incentives to the consumer to reduce their peak loads. These incentives either take the form of rate penalties for peak loads or reduced rates for electricity consumed during the utility's minimum load periods. The wastewater treatment plant offers the design engineer many opportunities for reducing peak loads and rescheduling other loads.

- Utilize the emergency generator for peak loads. This can take the mode of using enough emergency generating load to handle the plant peak load or to carry much of the plant operation during the utility's peak load.

- Provide influent surge capacity in order that overall plant load can remain more nearly constant. This mode of operation is discussed further under hydraulic flow regimes.

- Reschedule sludge processing operations such as dewatering, land application pumping, etc., to off-peak times.

- After a power failure, have an automatic sequencing or delay system to limit peak motor restarting loads.

2. Power Factor

The power load susceptible to power factor penalty rates can be reduced by the following techniques:

- Operate motors at 50 percent to 125 percent of rated load where their power factor is high. Below 50 percent load, the power factor rapidly decreases. High power factors can be achieved by intermittent operation of the motor or by having multiple motors to handle a varying load.

- Utilize modern high-efficiency electric motors which have high-power factors. The reduced power factor penalties and electricity consumption of these motors can rapidly pay for their extra cost.

- Install capacitors in parallel with the electric motor to correct the power factor.

3. Electric Motors

Consideration should be given to advanced motors and controllers.

- High-efficiency motors may be 15 to 25 percent more expensive, but their reduced electricity consumption can make their payback period as low as 2 to 4 years, out of a life of 10 to 15 years. Also, since they run cooler, they require less maintenance.

- Adjustable frequency source driven electric motors are more efficient. In one installation of a 75 horsepower motor, the use of a variable frequency source saved $6,200 a year over a liquid rheostat control, which rapidly paid back the additional cost of $8,000.

4. Lighting

While lighting is a minor consumer of electric power, even in this area noticeable savings can be made.

- Lighting can be zoned for two different illumination levels: one for safe access to and through the illuminated area and a second for operation and maintenance activities. For areas where operation and maintenance activities are infrequent, separate switch-activated systems can be added.

- Sodium vapor and metal halide lights can save 20 to 30 percent in electricity consumption over incandescent lights.

B. Hydraulic Flow Regimes

Significant electricity consumption can be achieved in the areas of overall plant operation and in the selection and operation of pumps.

1. Plant Operations

- Flow equalization, by providing surge capacity, can reduce peak power consumption by 20 to 30 percent. Also, by providing a more uniform flow, units can be operated more nearly at optimum efficiency.

- Adjust trickle filters to the actual operating conditions. A plant operating at 1:1 recirculation might still be able to meet effluent discharge limitations while operating at 0.75:1 or even 0.5:1.

- Rotating biological contactor systems should have the ability to leave a portion of the contactor system idle or to operate at reduced speed during periods of low flow.

- As mentioned earlier, provision can be made for intermittent operation of the sludge dewatering systems to permit them to operate at peak efficiency.

2. Pumps

- Constant capacity pumps operating at design loads are most efficient. By using multiple pumps and/or intermittent operation, a plant with varying flow can still efficiently use these types of pumps.

- Centrifugal pumps can be controlled with acceptable efficiency by throttling the suction. However, care must be taken not to plug the valve or cause solids to settle out.

- Axial flow pumps can not be efficiently throttled since power goes up with the head against which they are pumping.

- The output of positive displacement pumps can be efficiently varied by varying the speed. However, the motor must have an efficient means of varying its speed.

C. Air Consumption in Aeration Basins

Activated sludge aeration basins are the major consumers of power at wastewater treatment plants. Proper selection and operation of compressors and aeration basins can result in appreciable energy savings.

1. Air Compressors

- Air flow centrifugal compressors can also be most efficiently controlled by throttling suction.
- Positive displacement pumps can be controlled either by speed or by the use of multiple units.
- Air pumps lend themselves to automatic control systems that match air flows to air needs.
- The proper maintenance of air compressors is very important; particularly bearings, seals and clearances. Dirty filters can increase the suction pressure drop by up to 20 percent.

2. Aeration Basin

The longer the solids retention time the greater the aeration energy consumption. However, there is also less sludge generation, which might produce offsetting energy savings in the sludge processing system.

D. Thermodynamic Budgets

Careful management of the thermal energy in the plant stream can also result in significant savings.

- Maximize sludge concentration going into an incinerator. One ton of sludge solids at a 16 percent solids concentration required 165 gallons of fuel oil at one plant, but only 85 gallons at 25 percent solids concentration. An advanced treatment plant in Rochester saved 5600 gallons of fuel oil a day by going to a continuous belt press filter rather than a vacuum filter. If there is a sludge incinerator available, consideration should be given to burning the bar screenings in it to reduce trips to the landfill site. Also, sludge digester heating requirements will similarly be reduced with greater concentration.
- At the Corvallis, Oregon WWTP the heat of compression from the air compressors is used to heat the operations building. Also, plant effluent is used in the air conditioner's condenser. The warmed water is then used in the chlorine injectors.

E. Utilization of Digester Gas

A significant advantage in using anaerobic digesters for sludge processing is that they produce methane. An anaerobic digester system can meet 75 percent of the power need of an activated sludge wastewater treatment plant. An optimized plant will produce 11,000 cubic feet of natural gas per million gallons of capacity. However, digester gas is low in specific heat energy and corrosive due to sulphur dioxide contamination. Before it can be used by on-site engines, the SO_2 must be reduced or removed, and before it can be piped any distance, the carbon dioxide in the gas must be removed.

F. Management

Proper management of the plant can result in energy savings.

- Be aware of the availability of critical supplies. Shortages of critical supplies may result in inefficient plant operation.
- Keep energy consumption records for the entire plant; particularly for individual plant operations. Changes in consumption rates can signal malfunctioning systems. Also, comprehensive records can be effectively used in plant upgrading design.
- The Design Engineer should design the plant to permit efficient operation during periods of energy shortages. As part of this objective, the plant should be designed to work with alternative fuels and chemicals.
- Chlorine residuals monitoring instrumentation should be included in the plant to permit exact control of chlorine injection rates. Significant savings in chlorine consumption while still meeting effluent standards can be realized.

III. SOLAR ENERGY

Characteristics of typical wastewater treatment plants may lend themselves towards the utilization of solar energy in the future to reduce energy consumption.

A. Low Temperature Processes

Both the activated sludge and anaerobic digesters operate at temperatures below 100 degrees F and, thus, are amenable to the use of single pane low temperature flat plate collectors. These collectors are the least expensive and reliable solar collectors available.

B. Acceptance of Diurnal Heating

The hydraulic residence time of an activated sludge system is long enough and the thermal mass of the aeration basins and clarifiers great enough to effectively store daytime heating on into the night. Anaerobic digesters have a similar storage capacity.

C. Wilton, Maine Solar Heated WWT Plant

A 450,000 gallon per day WWT Plant in Wilton, Maine has been built with an integral solar heating system. The solar heating system has the following features:

- The interior of the building is passively heated by southward facing windows inclined at 60 degrees.
- The rotating biological contactor (RBC) room is heated by a southward facing Trombe wall with natural convection. This wall is also inclined at 60 degrees to maximize winter heating and yet shed snow.
- A hydronic solar heating system operating at 120 to 140 degrees F is used to heat the anaerobic digesters to 95 degrees F. The methane generated is not needed for heating purposes and is therefore available for an electric generator. Another advantage of this system is that it is easier to store the digester gas than heat. Thus, there is no separate thermal storage system (except for the potable hot water supply).

EMERGENCIES

UNIT 14c

UNIT 14c - EMERGENCIES

OBJECTIVES

At the conclusion of this presentation the participant shall be able to:

- Identify the types of standby equipment available.
- Use proper procedures to determine capacity and type of equipment required for a given installation.
- Determine proper installation design and post-installation maintenance for a given system.

UNIT 14c - EMERGENCIES

I. INTRODUCTION

Emergency electric power during power failure is required in wastewater treatment plants to: (1) safely bring the plant to a shutdown condition and to provide power to maintain the plant in a safe condition, and (2) maintain operation of the plant. Batteries can usually supply sufficient power for the first situation but emergency powered generating equipment is required for the second situation.

A. Power Outages

The probable frequency and duration of power outages is a principal determinant in the selection of an emergency power system. Statistics on power outages are available to the Design Engineer from the utility or other local sources. National statistics are available from the Federal Power Commission.

- The primary causes of outage vary with service areas. While rural areas are more affected by adverse weather, urban areas are more affected by equipment failures, overloads and vehicle accidents.
- The primary consideration in wastewater treatment plant design is the length of the outage rather than the frequency. The duration of any outage is usually tied to the efficiency of the supplier for whatever the reason. Again, the local electrical distributor can supply this data.
- The possibility of outages or reduced voltage supplies connected with national energy problems is real. This is a situation which should definitely be considered in any design.
- Laws, codes, regulations, etc., are not made a part of this presentation, but these regulatory factors are major considerations for selecting alternate power sources.
- While this presentation is limited to on-site generation, it is possible to provide a facility with redundancy of service through two or more utility sources. This has been done to satisfy regulatory requirements in several instances. In some facilities, this second utility source has been supported by on-site generation. Dual utility sources are effective for isolated faults, but are not effective for more widespread

faults such as weather, etc. The most limiting factor when considering dual utility sources is availability.

B. Types of Emergency Systems

When considering alternate power sources, dependability is the major consideration. The most dependable alternate source of power is that generated on site. While standby generating plants are available in a variety of fuels including gasoline, natural gas, LP gas and diesel fuel, this presentation is limited to those units powered by diesel engines, since this type of fuel and design is most economical in units above 100 KW. Due to the design criteria of most treatment facilities and pumping stations, the standby units are above 100 KW. An ideal generating plant has adequate capacity and performance to meet the requirements of the load it serves. Some of the types of emergency systems are described below.

- A standby emergency electric power system is one which normally stands unused. It starts and assumes the load when the normal electric power service fails and supplies the load until return of the normal power source.
- Supplementary standby (portable) is an electric plant that may have a variety of uses other than the standby for which it is designed. A good example of a supplementary standby unit is a trailer mount for a portable diesel electric plant that is sized and designed to provide standby power for a pumping station or water treatment plant, but can be used for other purposes when not needed for that use.
- A peaking power system is one which is used to supplement the normal electric power source during periods of peak demand and is used in an application commonly known as "peak shaving" to provide maximum power at a reduced rate for the consumer.
- Prime power systems are those where the diesel generator is the normal source of power and operates to provide power to the load on a continual basis.
- Total energy systems are those where the diesel generator is used to supply normal electric power and heat and steam is recovered from the engine itself for other uses in the plant.

II. SYSTEM SELECTION

The selection of the component of an emergency powered generating system is dependent upon the type of system. Having selected the type of emergency system, it is then possible to determine the specifications of the individual components in the system.

A. Number of Units

Single unit diesel generators are the most economical and most common arrangement of a standby plant and are sized to the proper capacity to carry the emergency load. Multiple units would involve two or more diesel generators sized to carry separate portions of the emergency load. These units are most commonly used where different portions of the emergency load are of a different system voltage.

Parallel units are used when the size of the diesel generator precludes adequate capacity in a single unit or redundancy is desired in the emergency system. Parallel units are generally of the same capacity and of necessity, the same voltage, and are manually or automatically paralleled to serve a single load.

B. Capacity

The basic requirement of an electric plant is to provide enough KW capacity to serve the peak load or the maximum load in kilowatts that the electric plant will be expected to serve. It may be the total KW load, but it is often less because there will never be any one time when all connected loads will be operating. However, the total load of the emergency electric plant may be the complete building load or it may be the selected essential loads known as an emergency circuit. Diversification will determine the actual capacity requirement of the emergency generator.

- When motors are started at full voltage, they draw more power than their maximum running load KW. Particular attention must be given to high motor load circuits since the in-rush KVA has an adverse effect on the design capacity of the emergency generator. Not only must total motor horsepower be considered, but also the frequency of operation of this motor load. In order to properly size a diesel generator, many facts must be determined. This information should include, but not be limited to, the following:
  - Application
  - Peak KW load
  - Estimated power factor of load
  - Voltage and phase
  - Ambient conditions
  - Limits of frequency variation
  - Limits of voltage dip and recovery time
  - Lists of motor sizes and starting characteristics

  - Information as to the amount of load that could be on the line when large motors are started

- It is often tempting to specify excess capacity to insure a safety margin; however, in a diesel generator excess capacity can many times be quite harmful. Unburned fuel may be introduced into the lube oil or the exhaust system and a general gumming up of the diesel engine under partial load may occur.

- It is normally not necessary to specify engine horsepower when specifying a KW capacity. Generally, the electrical performance criteria of the electric plant is adequate with the particular manufacturer determining the engine horsepower and size of the engine required to produce the electrical performance specified.

- The generator must have the capacity to serve the peak KW load required at the load power factor where large motors are started across the line. This effect can actually be the controlling factor in establishing required generator capacity. The generator size based on peak load is compared with the size of the generator required to avoid excessive voltage dip. Whichever is larger becomes the required generator KVA capacity. The peak load may be the maximum steady load or it may be the steady load plus the extra KW drawn by motors when starting, if motors actually start during a peak load. Where quality of lighting, quality of voltage or limits of voltage are important, voltage dip limits must be established. While most industrial equipment can tolerate voltage dips of up to 35 percent, some equipment may not accept a voltage dip of more than 5 percent. This factor must be considered in sizing the unit. The primary method of reducing the required generator capacity in a high motor load application is to regulate the method and sequence of motors starting on the emergency circuit.

C. Rating

Generators are manufactured in a variety of nominal sizes and ratings and may be built to match the exact requirements of an application. The most common alternator used today is a single bearing type which is coupled directly to the engine drive system with a rear single support bearing.

- An electric engine set must have enough capacity to serve the peak load and adequate power margin to recover frequency after abrupt load changes. For this reason, so called "flash ratings" are not acceptable. The power rating used should be the rating established by the engine manufacturer to afford adequate engine life in the type of service for which it is intended. There are two basic unit ratings in use today. The continuous rating is that rating used when the electric plant is to be the prime source of power and operates on a continuous basis while achieving maximum engine life. The standby rating is the rating of the engine when used as the standby to another source of power, and which provides emergency power continuously during a power outage. The normal baseline that should be established regarding ratings of the diesel engines should be for the actual job site rating in feet above sea level, design ambient temperature, etc.

- An alternator operates at a single synchronous speed to produce a specified frequency, normally 60 Hz. The design most in use today is the four pole alternator that rotates at 1800 rpm to produce a 60 cycle current. Included as a part of the generator is the exciter which supplies dc to the field to magnetize the rotating poles. One type in use today is the rotating alternator with a rotating rectifier in a stationary exciter field. Most generators in use today are of the brushless type. Commercial generators are designed for proper cooling at the nameplate rating. Normally, generators used in sewage treatment plants or pumping stations would be of the drip-proof type and are generally oversized to allow for temperature rise within NEMA limits. The rated capacity of a generator is stated on the nameplate in terms of KW, KVA, voltage, power factor and temperature rise. While the electric plant may have various ratings, the most common would be the continuous standby rating. This rating is applied to those plants that provide continuous power for the duration of normal utility outage. Class of insulation should not be specified. Rather, specification should include load, type of duty, maximum temperature, altitude, power factor and other design criteria, and it should be stated that the supply is within NEMA limits.

D. Voltage Regulators

Most voltage regulators in use today are the solid-state type without any mechanical contacts. A generator equipped with an automatic voltage regulator maintains approximate constant voltage at any steady load but the voltage may vary slightly above and below the average. Sudden load change causes a momentary voltage deviation. The voltage then recovers and settles out near its former level. The momentary dip or rise as load is applied or removed often must be limited to avoid light flicker or malfunction of sensitive equipment. The table below shows typical voltage regulation characteristics of a diesel electric generator set.

	General Applications	Precise Applications
Voltage Regulation	4.0 percent	1.5 percent
Maximum Voltage Variation at Constant Load Stability	±2.0 percent	±0.5 percent